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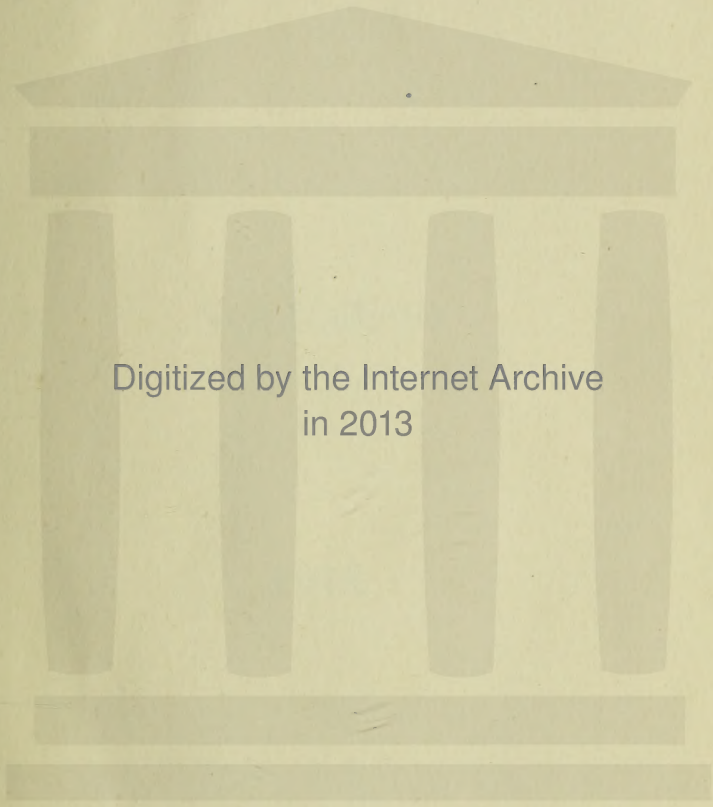

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ERRATA.

Page 25, Table 2, column headings "Hard" and "Soft" are reversed throughout.

Page 83, name of author of paper is Albrecht, not Aldrecht.

Date of issue of No. 4 should be April 25, 1918.

Plate 4, facing page 151, figure 2 is reversed.

Page 180, line 7 was carried down with footnote 2 and second line of this footnote precedes the first.

Page 280, line 8, and page 281, line 1, read "Plate 9" for "Plate 7."

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VARIATIONS IN SEED TESTS RESULTING FROM ERRORS IN SAMPLING.[1]

O. A. STEVENS.

INTRODUCTION.

Little attention appears to have been given to careful study of the accuracy of seed testing. Some experiments have been made during the past few years by sending to different laboratories samples drawn from a common bulk. The results of one of these has been published (Stone, 1913),[2] but so far as the writer could find from available literature no attempt had been made to analyze the fundamental factors to which variations are due. In this paper the results are presented of some investigations conducted during 1914 and 1915 when routine duties were not pressing.[3]

CAUSES FOR VARIATION.

Variations in the results of seed testing are fundamentally of two kinds, and are to a great extent impossible to avoid. One is purely mathematical, the other personal or to a large extent economic. The direct causes may be listed as follows:

[1] Contribution from the Department of Botany, North Dakota Agricultural College. Received for publication May 14, 1917.

[2] Bibliographical citations in parentheses refer to "Literature cited," p. 19.

[3] The author is indebted to Prof. I. W. Smith for assistance with the mathematical portion of the work. Credit is also due student assistants as follows: Mr. M. S. Hagen for all of the germination work except two lots of 50 each; Mr. A. M. Christensen for the series of alfalfa purity tests and two of germination; and Mr. Sidney Hooper for one series of purity tests of flax.

In Purity Tests.	In Germination Tests.
Imperfect mixing.	Imperfect mixing.
Effect of random sampling.	Effect of random sampling.
Errors in weighing.	Errors in counting.
Effect of personal selection.	Effect of personal selection.
Errors of identification.	Improper conditions for germination.
	Special conditions of the seed.

Considering a sample from its point of origin the first source of variation is in drawing a small sample from a large bulk. The accuracy with which this sample represents the bulk depends upon the uniformity of the latter. This would depend upon the uniformity of the field or whether different lots had been mixed to make up the stock. When samples are drawn and mailed by various parties, there is greater possibility of variation than if all could be taken by the same person. When the analyst receives the sample and takes from it a standard sample for analysis the same factors are again operative.

Before the standard laboratory sample is taken, the entire lot should be mixed as thoroughly as possible. If the seed has been well cleaned, it is doubtful if any mixing is necessary. In poorly cleaned seed there are usually elements of different nature which tend to collect at certain places, such as sand, fine dirt, or small seeds at the bottom, and broken stems, etc., at the top. In such samples it may be difficult to make an even mixture, and it is desirable to separate such materials roughly from the entire sample. It may be observed that in such cases the error in drawing the sample from the bulk is likely to be large, and a careful analysis is scarcely worth the while.

After a sample has been mixed as well as possible, a small portion will not accurately represent the entire amount. If, for example, we take one seed out of a lot of one hundred which are half of one kind and half of another, it will give no estimate of the proportions of the mixture. As we take a larger number, the degree of accuracy increases, but can not be perfect unless the entire number is used. This is what is here referred to as fundamentally a source of mathematical error. This error can not be avoided, but it is possible to determine its approximate limits under given conditions and thus make allowance for it.

There is a certain amount of personal error in weighing out a standard sample for analysis, or in counting a certain number of seeds for germination tests, but this is an occasional factor rather than a constant one, as are most of those under consideration.

The error of personal selection is of considerable importance. In germination work it may be a tendency to pick out the better seeds.

There should, of course, be a standard method which would prevent this, yet it is not entirely possible. The seeds for germination should be selected from the pure seed after the purity test has been completed; but the length of the germination period is the factor which determines the time necessary for a report. Under the usual relation of amount of work to the equipment of the laboratory, time is saved by starting a germination test at once.

There is in nearly every sort of seed an indefinable line of separation between pure seed and inert matter, *i. e.*, shrunken seeds, broken seeds, and grass florets without caryopses. One may make an arbitrary division, but there will be cases coming so close to the line that they might be placed on either side. For instance, if half a seed be placed with the inert matter, and more than half with the pure seed, there will be found individuals that are not readily placed. A single instance of this in case of flax will make a difference of 0.02 percent of 10 grams. With wheat a single such grain would amount to 0.05 percent of 30 grams.

With grasses we may consider florets without caryopses as inert, but they occur in all degrees of development and are not always easily placed in either one or the other class. It should be noted, however, that these things occur most frequently in low-grade seed, in which small errors are not of great consequence.

The error of identification should not be of consequence in most cases, but there are instances where it is likely to be. We may simply mention, in passing, the difficulty of separating such seeds as alfalfa and sweet clover, meadow fescue and perennial ryegrass, species of bluegrass, species of Agropyron, etc.

The variations so far discussed apply to both purity and germination tests. There are also causes of variation peculiar to the latter, such as methods of testing and various factors modifying the condition of the seed. Certainly, unusual variations may be expected if the temperature and moisture conditions of the germination chamber are not adapted to the seed. The failure to secure satisfactory results by handling bluegrass or other small and slowly germinating seeds by the same methods commonly used for clovers or cereals is a good example of this. Seeds not sufficiently aged for prompt germination may respond better to conditions somewhat different from those usually employed for that kind of seed. Fresh seed of lettuce is one example which has caused considerable trouble in this way. Barley and oats slightly damaged by exposure to water or frost have also been a source of difficulty.

By the economic factor is meant the lack of funds to secure proper equipment or to employ workers of sufficient ability and training.

If the results of a series of analyses of samples drawn from a carefully mixed bulk and submitted to a number of laboratories are examined (Stone, 1913), the effect of these two primary factors of error is readily seen. The mathematical variation may be readily demonstrated from some of the germination tables, as will be shown later in connection with the experimental data presented. From an inspection of the purity table of bluegrass or orchard grass it may be seen that some reports give an unusually high percentage of pure seed and a correspondingly low percentage of inert matter. This is no doubt due to the inclusion in pure seed of the florets containing no caryopses. This may have been due to insufficiently trained analysts or to lack of equipment (vertical air blast separator, etc., without which such separation is quite difficult). From the table of bluegrass germination we note some very low results and some blanks probably due to a lack of equipment.

Much of the personal factor depends upon experience, not only general, but with an individual class of seeds. The workers of a laboratory in a State where a certain crop is grown little or not at all can not be expected to be as familiar with the seeds of that crop as those who have constant occasion to examine them.

Experiments with Germination Tests.

The work here described was undertaken to determine the mathematical error in germination tests. The general plan was to make a series of 50 tests from one lot of seed and to calculate the standard deviation and probable error, these tests being made simultaneously by one person.

To reduce the sources of variation as much as possible, it seemed desirable to make a series of theoretical tests. A sample of seed to be tested for germination may be regarded as a mixture of two sorts, the one viable, the other not. The result then depends upon the perfection of the mixture and the chance of selection in a given number.

After some preliminary experiments a white-seeded kafir was selected as best suited to the purpose. Part of the seed was stained with Delafield's hæmatoxylin, the alcoholic solution being used in order to prevent, as far as possible, any change in the seed.

The first question was to determine what mixing was necessary. For this purpose 55 grams of each color were placed together and poured from one dish into another. Small pans holding several times

this amount were used and the seed poured from one to the other at the rate of fifty times per minute, the pans being about 6 inches apart. This process was repeated 25, 75, and 200 times and then the series repeated with the results shown in Table 1.

TABLE 1.—*Probable error in selecting 100 seeds from a mixture of equal parts of two sorts.*

Number of trials.	Mixed 25 times.	Mixed 75 times.	Mixed 200 times.
First	3.10	2.88	2.83
Second	3.05	2.83	2.82

The results of the trials are very close, in fact remarkably so, considering the differences in later experiments. It is rather surprising also how little difference appears from the longer continued mixing. In the following work 75 mixings were made, the operation being as nearly uniform as possible throughout the series. In counting out 100 seeds the practice followed was to pour the entire lot upon the work table and, by placing a hand on each side, draw out one end

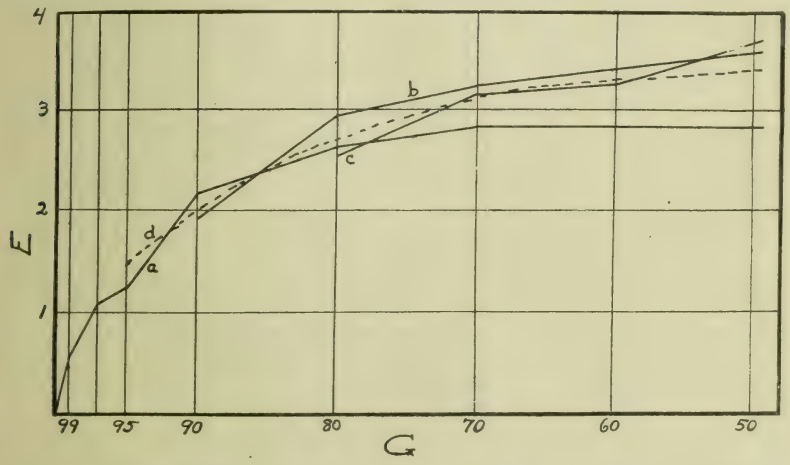

FIG. 1. Graph showing probable error in selecting 100 seeds from mixtures of different percentages. *G*, Percentage of germination; *E*, percentage of probable error; *a*, no hard seed present; *b*, 5 percent dead, the remainder hard; *c*, 10 percent dead; *d*, from Table 12 (Rodewald, 1889, p. 110).

of the pile to a narrow point. It would be preferable to have a mechanical means, such as weighing out the number. This was not used in the present case on account of the impossibility of taking just 100 seeds and the work involved in calculating odd numbers.

The method used should obviate the possibility of unconscious selection.

The second problem was to determine the error for a given percentage. In a 100 percent stock there could be no variation. As the percentage decreases from this point we may expect the variation to increase until 50 percent is reached, then decreasing again to zero. In actual tests the poorly germinating seed might show a comparatively greater variation on account of failure to respond to slightly varying conditions.

A series of mixtures was prepared and carried through with the results shown in Table 2. Inasmuch as the hard seeds of legumes introduce a third factor, two additional series were run, using 5 and 10 percent respectively as dead, the remainder being considered hard (dead represented by seeds colored with an alcoholic solution of erythrosin).

TABLE 2.—*Probable error in selecting 100 seeds from mixtures of different percentages.*

Percentage calculated viable.	Error in viable series.			Error in hard series.		Error in dead series.	
	With 0% hard.	With 5%. dead.	With 10% dead.	With 5% dead.	With 10% dead.	5%.	10%.
50	2.88	3.63	3.67	3.60	3.14	1.92	1.98
60	2.89	3.42	3.29	3.44	3.11	1.84	2.27
70	2.91	3.24	3.13	3.08	2.98	1.55	1.94
80	2.69	2.95	2.60	2.38	2.07	1.14	1.98
90	2.22	1.95		1.36		1.28	
95	1.30						
97	1.15						
99	.64						

The results in the first three columns are shown graphically in figure 1. In the results of the second and third lines of the second column an extreme variation was obtained (2.81 and 3.99). A second trial of this was made with the results shown.

Where only two types of seeds are present the variation of the one must be the same as that of the other, since the second always equals 100 minus the first. Therefore, the variation in a 10 percent series would be the same, at least theoretically, as in a 90 percent series, etc., and the greatest variation would be found when each is 50 percent. When three types are present the number of possible combinations is increased and the variation of one series need not be the same as either of the others. The greatest variation would be expected when the percentage of each is equal. Accordingly, one lot was made up in this manner and the probable error found to be 3.83,

3.92 and 3.01 respectively for the three sorts. The deviation of each is shown in figure 2.

Two more series were run with this material and will be mentioned later. Several series of germination tests were also made and the probable error calculated in the same manner. In order to eliminate other factors as far as possible, seeds were used which do not offer special difficulties. All tests were made between folds of blotting

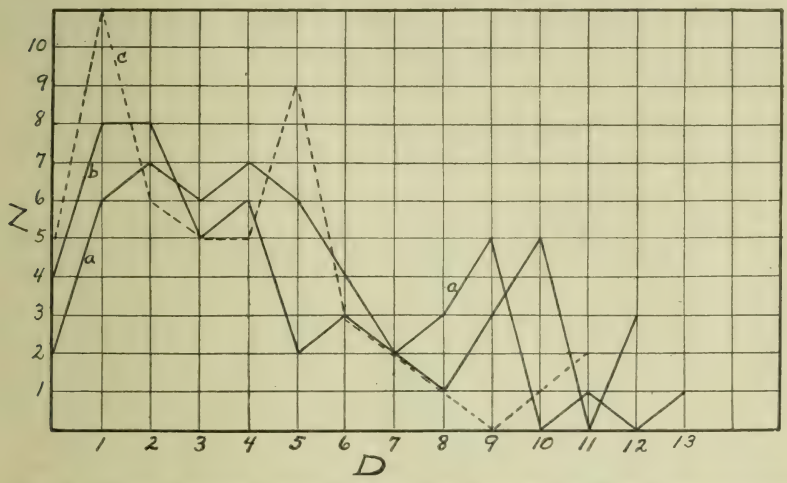

FIG. 2. Graph showing deviation from the mean of each of the components in a mixture of equal parts. *N*, number of deviates in 50 tests; *D*, percentage of deviation in 100 seeds.

paper in the standard germinating chamber at alternating temperature, and each set of 50 was made at the same time by the same person. For sake of comparison, the results of four lots tested by about 20 different laboratories (Stone, 1913), have been calculated and added. These figures are shown in Table 3.

TABLE 3.—*Probable error in germination tests.*

Kind of seed.	No. of tests.	Percentage of germination.	Probable error in test of 100 seeds.
Alfalfa No. 1	50	50 (48 hard)	4.03
Alfalfa (2d trial)	50	50 (48 hard)	3.35
Alfalfa No. 2	50	92 (2 hard)	1.89
Alfalfa No. 3	50	85 (13.5 hard)	1.81
Alfalfa No. 4	50	91 (4 hard)	2.14
Millet	50	91	2.58
Bromus	50	97.5	1.18
Alfalfa	19	96	1.99
Red clover	18	91	2.43
Millet	18	93	1.97
Timothy	18	92	2.20

The preceding work is based upon only 100 seeds for each test. The next question is to what extent the error would be reduced by using a greater number. For this purpose several series of 200 tests each were made in the same manner as before, but each lot of 50 was run at a different time. The results have been calculated for each set of 50 tests, then for each set of 50 obtained by taking the mean of the first and second, third and fourth, etc., and in the same manner for the means of each set of three and four tests, thus giving series based upon 200, 300, and 400 seeds respectively. The results of these are shown in Table 4.

TABLE 4.—*Probable error in using 100, 200, 300 and 400 seeds.*

Kind of seed.	Percent of germination.	Number of seeds in test.							
		100.				200.		300.	400.
		1st set.	2d set.	3d set.	4th set.	1st set.	2d set.		
Millet	72.0	3.51	2.98	3.09	[a]	2.47	[a]	2.25	
Alfalfa	83.0 (9 hard)	2.49	2.62	2.48	3.02	3.01	2.27	1.82	1.43
Do	56.5 (35.5 hard)	4.10	3.63	3.32	3.51	2.79	2.53	2.72	1.91
Flax	99.0	.68	.81	.61	.79	.47	.52	.37	.37
Kafir	[b] 60.0 (32 hard)	3.53	3.78	3.24	3.26	2.72	2.26	2.10	1.82

[a] Only 150 tests made.

[b] Not germinated; mixture as in Table 2.

As this method of comparing such data may not be considered permissible, an 80 percent mixture was prepared and a further series of 500 lots of 100 each were counted. The rata thus secured were calculated in four distinct groups and also in combinations as in the former cases, with the following results.

For 100 seeds—2.65 (1st lot of 50);
For 200 seeds—1.78 (2d and 3d lots used as 50 of 200 seeds);
For 300 seeds—1.50 (4th to 6th lots used as 50 of 300 seeds);
For 400 seeds—1.35 (7th to 10th lots used as 50 of 400 seeds).
For each of 10 lots of 50 of 100 seeds each—2.65, 2.55, 3.11, 2.70, 3.21, 2.36, 2.95, 2.41, 2.14, 2.96.
For each of 5 lots of 50 of 200 seeds each—1.69, 1.76, 2.13, 1.77, 1.88.
For each of 3 lots of 50 of 300 seeds each—1.64, 1.50, 1.34.
For each of 2 lots of 50 of 400 seeds each—1.19, 1.35.
For each of 2 lots of 50 of 500 seeds each—1.08, 1.25.
For 1 lot of 1,000 seeds each—0.85.

Figure 3 shows the deviation of 200 lots in the third and fifth series of Table 4 and also for the 500 last mentioned. This figure shows again how little the variation at 50 percent differs from that at 80 percent.

By using less than 100 seeds in each lot the error would be considerably increased. One trial of a 50 percent mixture, using 50 lots of 50 and 25 seeds each, gave probable errors of 4.26 and 6.73 respectively.

Another question arises in this connection. If the results of two tests vary rather widely, does it follow that the mean of the two is farther from the mean of the series than when the variation between

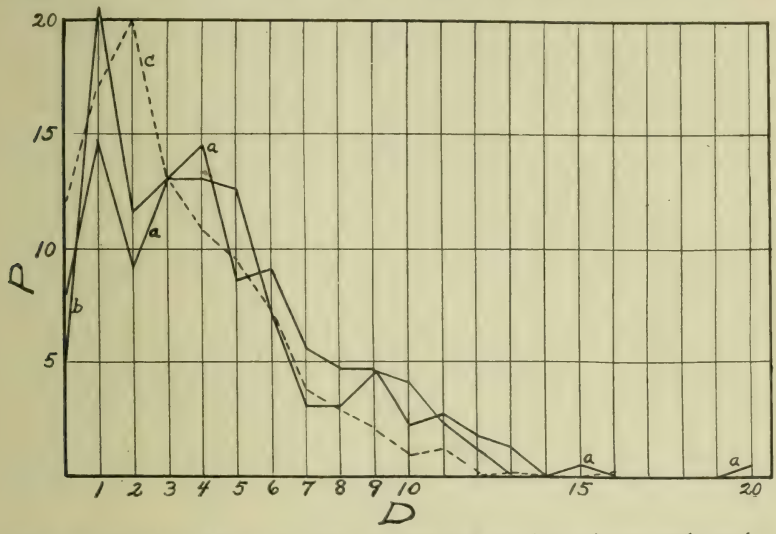

FIG. 3. Deviation from the mean of 200 and 500 lots of 100 seeds each. *P*, percentage of deviates; *D*, percentage of deviation; *a*, alfalfa having 56.5 percent viable and 35.5 percent hard seeds; *b*, Kafir mixture, 60 percent calculated viable and 32 percent hard; *c*, Kafir mixture, 80 percent calculated viable and 20 percent dead.

two tests is less? In other words, is it necessary to make a retest when more than a certain variation occurs between duplicate tests?

To throw some light upon this point the second and fifth series in Table 4 were used. The mean of each successive pair (1st and 2d, 3d and 4th, etc.) was found and the deviation of these means from the mean of the entire series of 200 was found. When these differences are arranged according to the variation of the two tests of each pair the results shown in Table 5 are produced.

The data from the last series of 500 tests were also handled in the same way and in addition the percentage of cases where the mean of the pair exceeded the mean of the entire series by more than the probable error of 200 seeds was found for each group. These data are given in Table 6.

TABLE 5.—*Deviation of duplicate tests.*

Variation between the members of each pair.	Deviation of mean of each pair from mean of entire series.			
	Alfalfa series.		Kafir series.	
	Number of deviates.	Average deviation.	Number of deviates.	Average deviation.
		Percent.		*Percent.*
0	2	2.0	5	1.6
1	7	3.7	9	2.8
2	11	2 8	9	2.7
3	9	2.8	13	2.3
4	9	2.7	10	3.3
5	10	2.7	9	3.6
6	17	3.5	14	2.4
7	8	2.9	6	4.8
8	2	3.0	8	2.1
9	6	4.4	4	5.4
10	2	6.0	4	4.5
11	6	4.5	1	1.3
12	1	2.5	1	1.2
13	2	3.5	1	3.3
14	5	4.2	3	3.4
17	1	4.0	1	3.3
18	0		1	.8
21	0		1	1.7
22	1	1.5	0	
24	1	7.5	0	

TABLE 6.—*Variation of duplicates in 500 lots of 100 seeds each, counted from an 80 percent mixture.*

Difference between duplicates.	Number of cases.	Average deviation.	Number exceeding probable error.	Percentage exceeding probable error.		
				Individuals.	3 groups.	2 groups.
Percent.		*Percent.*				
0	17	2.0	11	65		
1	40	2.0	12	30		
2	29	1.8	14	48	45	
3	27	2.1	10	37		48
4	25	2.2	15	60		
5	22	2.4	11	50		
6	23	2.5	15	67		
7	13	1.7	2	15	52	
8	10	1.5	5	50		
9	7	3.7	6	86		
10	12	2.0	4	33		46
11	9	3.7	6	67	49	
12	9	2.2	4	44		
13	4	2.5	2	50		
14	3	1.7	2	67		

There is at present a ruling adopted by the Official Seed Analysts of North America that retests should be made when the variation in duplicate tests of 100 seeds each exceeds the following:

6 percent for a germination of 90 percent or more;
7 percent for a germination of 80 to 90 percent;
8 percent for a germination of 70 to 80 percent;
9 percent for a germination of 60 to 70 percent;
10 percent for a germination of 50 to 60 percent.

The writer believes that this regulation is of doubtful value in that it is quite possible for the variation to be greater than this without destroying the value of the test; further, that it is likely to cause an unwarranted faith in results which show smaller variations.

From Table 6 it will be observed that slightly over 20 percent of the series would be subject to retest by the above ruling. The fifth column of the table shows the percentage of cases in which the mean of each pair of tests exceeds the mean of the entire series by more than the probable error of a test of 200 seeds. Since by the nature of the probable error it is exceeded by half of the cases, the amounts in this column should average about 50 percent. If the duplicates which differ more than 7 percent are not to be relied upon, we should expect to see the values in this column higher for variations above 7 percent than for those below. It will be seen from the table that this is not the case; that approximately the same number of high and low values occur in different portions of the column, and that by collecting the results in two or three groups, very little difference is found.

Of the 250 duplicates, 46 showed a difference of over 8 percent between the two members. The average deviation of the means of these 46 from the mean of the entire series was 2.35 percent, while in the other 204 cases it was 2.06 percent. Further, in only 24 of the 46 was this deviation greater than 2 percent (probable error in test of 200 seeds is 1.87 percent). This seems to show plainly that in this case wide variations between duplicate lots did not appreciably reduce the accuracy of the result.

In Table 5, 9 of the 100 duplicates of the kafir series showed a difference of over 10 percent between the mean of the two tests and the mean of the entire series. The average deviation of the means of these 9 from the mean of the entire series was 2.44 percent; that of the other 91, 2.97 percent. Only in 4 of the 9 did this deviation exceed the probable error of 2.2 percent.

In the alfalfa series given in the same table, 17 of 100 exceeded the limit of 10 percent, the average deviation being 4.15 percent, and 12 of the 17 exceeding the probable error. The average deviation of the other 83 was 3.44 percent.

The results of this alfalfa series seem to oppose the writer's contention, yet the data are few and the kafir series tends the other way to about an equal extent. It is to be noted further than among duplicates showing only slight variations the means may differ widely from the mean of the series. For instance, in the alfalfa series just mentioned there is one case among the duplicates which vary only 1 percent in which the mean of the two differs from the mean of the series by 9 percent; among those differing by 2 percent, there are two showing 6.5 percent and one 5.5 percent, etc.

This is a point which the writer wishes to emphasize especially. If duplicates vary only slightly, it is still uncertain that their mean is accurate to a similar degree. If the conditions for the test are unsuitable this will be even more the case, for if one test fails to germinate properly the chances are that the duplicate will do the same.

Variations in Purity Tests.

A large number of factors are concerned in the variations in sampling for purity tests, since each of the three chief components of the sample (foreign seed, inert matter, and pure seed) may have a variable number of components. The size and number of the various foreign seeds will play an important part. Thus it may be difficult to find a value of accuracy which shall serve for a large range of cases.

In the following experiments the general plan was the same as in the preceding, viz., 50 tests of each lot made by the same person, the seed used being such that unusual variations would not be encountered. In taking the standard samples for analysis the seed mixer and sampler[4] was used, but the last separation was corrected to the standard weight by dipping out with a spoon or adding in the same manner from the other portion of the separation. The entire lot was not separated each time, enough for several tests being set aside toward the end of the process, this finished, and a similar amount set aside from another separation of the bulk. The bromegrass, although a fairly clean lot, would not run through the mixer, and was poured into a pan, portions being taken from different parts for each lot tested. The results are shown in Table 7.

The large error in foreign seed of the bromegrass is due to occasional seeds of barley and wild oats. Such an occurrence is common in the homegrown bromegrass seed examined by us. Similar condi-

[4] Rules and apparatus for seed testing. U. S. Dept. Agr., Office of Experiment Stations Circ. 34, rev. ed., p. 12. 1904.

TABLE 7.—*Probable error of purity tests as determined with the seeds of several crops.*

Kind of seed.	Number of tests.	Quantity used.	Pure seed.	Foreign seed.	Inert matter.
		Grams.	*Percent.*	*Percent.*	*Percent.*
Flax No. 1.....	50	10	97.88± .15	0.63±.06	1.49±.13
Flax No. 2.....	50	10	97.18± .17	1.17±.13	1.65±.13
Alfalfa.....	50	5	98.00± .17	1.56±.16	.44±.07
Bromegrass.....	50	3	89.40±1.00	.28±.32	10.18±.87

tions may be met elsewhere, and in ordinary work the result should be corrected from the examination of a larger quantity for such impurities, if it is apparent that the result would be materially changed thereby.

In all but the last of the above series the percentages were calculated to the second decimal. To show further the value of this, the probable error was calculated for the first two a second time, using only one decimal, with the results shown in Table 8.

TABLE 8.—*Value of second decimal in calculating probable error of purity tests.*

Test.	Percentage.	Probable error.	
		Using two decimals.	Using one decimal.
Flax No. 1.		*Percent.*	*Percent.*
Foreign seed.....	0.63	0.062	0.068
Inert matter.....	1.50	.129	.147
Pure seed.....	97.88	.155	.157
Flax No. 2.....			
Foreign seed.....	1.17	.132	.119
Inert matter.....	1.65	.133	.143
Pure seed.....	97.18	.171	.172

The variation in number of foreign seeds of a given species from the tests reported in Table 7 is shown in Table 9.

TABLE 9.—*Variation in number of foreign seeds in purity tests.*

Seed examined and foreign seed contained therein.	Average number.	Probable error.
Flax No. 1:		
Chætochloa viridis	29.3	3.8
Chætochloa glauca	9.4	1.6
Echinochloa crusgalli	1.2	.7
Chenopodium pratericola	.7	.5
Flax No. 2:		
Chætochloa viridis	14.0	2.1
Chætochloa glauca	36.6	4.4
Alfalfa:		
Chenopodium album	88.5	7.4
Ambrosia artemisiæfolia	1.2	.8
Helianthus sp.	1.7	1.0

Seed examined and foreign seed contained therein.	Average number.	Probable error.
Bromegrass:		
Agropyron tenerum	1.4	.8
Lappula lappula	.3	.4
Polygonum convolvulus	.4	.4

One attempt was made to ascertain the variation due to personal selection. The last lot in the first flax series was thrown back together and reworked three times by three analysts, the weighing of each separation being made by one of the other analysts in order to avoid unconscious selection in the next test. The results are presented in Table 10.

TABLE 10.—*Variation in separation of the same sample by different analysts.*

Analyst.	Foreign seed.			Inert matter.		
	Test No. 1.	Test No. 2.	Test No. 3.	Test No. 1.	Test No. 2.	Test No. 3.
No. 1	.71	.70	.71	1.34	1.12	1.33
No. 2	.72	.71	.73	1.25	1.20	1.47
No. 3	.72	.72	.72	1.14	1.20	1.46

As the foreign seeds were identical in each case the difference in those columns must be due to inaccuracy in weighing. The balance used was an inexpensive one, but the variation is not of significant value. In case of the inert matter one factor is the distinction between various conditions of broken seeds, these comprising most of the quantity. Further tests of this sort are desirable, but they are difficult to control properly.

CONCLUSIONS AND RECOMMENDATIONS.

1. The probable error of a single germination test of 100 to 400 seeds varies according to percentage of germination as shown in Table 11.

TABLE 11.—*Approximate probable error for germination tests.*

Number of seeds used.	Percentage of germination.				
	99.	97.	95.	90.	80 to 50.
100	.75	1.00	1.50	2.25	2.80
200	.50	[a].70	[a]1.00	[a]1.50	2.00
300	.40	[a].55	[a].80	[a]1.20	1.75
400	.35	[a].50	[a].70	[a]1.05	1.50

[a] Estimated from the value next above by reducing it in proportion to the results in the first column.

The above figures are increased about one-fifth in the lower percentages of germination for legumes containing the so-called "hard" seeds. This is for work in which the sources of variation are reduced as far as it is possible to do. No attempt is made in this paper to determine the range of variation where factors other than that of mathematical probability enter to any extent. These values may also be used for other experiments involving similar conditions, e. g., counting 500 seeds to determine percentage of mixture of two kinds.

2. For samples not containing mixtures of materials which tend to separate readily (such as sand, fine trash, or coarse material), only a small amount of mixing of samples seems necessary. Samples which do contain such mixtures should receive, when practical, a supplementary test of larger quantity to show the approximate quantity of such materials. For example, these may be separated first by a sieve, and the percentage added to that obtained by a regular test from the remaining quantity.

3. For purity tests the accuracy depends upon many factors. The quantities used should receive a careful investigation in order to determine whether those in current use could be changed to advantage. The use of the second decimal place is of no value in most work. If such accuracy is desired, the test should be based upon a sample of sufficient size.

An instance of such change may be cited in some work carried on at this laboratory in connection with the Improved Seed-Growers' contest. The following schedule was adopted and the second decimal used. For cereals a measured quantity (about 8 ounces for wheat) was used unless the seed was obviously impure, and then the regular quantity (30 gr.) was taken. For flax and smaller seeds, three times the regular quantity was taken unless decidedly impure. This is not suggested as a new basis, but merely mentioned as an instance of a sliding scale which has been used to advantage. In this work the number of seeds of certain noxious weeds, such as wild oats, mustard, etc., was calculated from the larger sample. This is quite an important point and should be carried out for any sorts that are considered of special importance.

4. Results of seed tests should be accompanied by an indication of their accuracy. The regular way of expressing this is by writing the probable error after the result, e. g., 95 ± 1.5 percent, thus indicating that the result probably lies between 93.5 percent and 96.5 percent. For ordinary reports it would be desirable to have some form by which it would be stated more completely.

While the probable error represents a very definite quantity, so far as the data from which it is derived are concerned, its practical application is somewhat difficult. Using again the figures of the preceding paragraph, the probable error represents only an even chance that the true result lies within 1.5 percent of 95 percent. The chances are as great that it lies beyond this. If the probable error is doubled, there are about four chances in five that it lies within this figure (95 ± 3, i. e., between 92 and 98). Placing this in another form we see that by allowing twice the probable error, our results will still be beyond this in 20 percent of the trials. This is surely the smallest reasonable allowance that can be made. Then for the smallest practical scale of allowance for variation, the figures in Table 11 should be doubled.

5. Table 8 indicates that the second decimal place is not necessary for the calculation of probable error in such tests. This is quite important as the use of the second place involves several times as much labor in calculating.

6. The amount of seed used for tests (and therefore the degree of accuracy obtained) must be regulated by two factors, viz., the degree of accuracy necessary for dependable results and the amount of work which it is possible to handle. From the data presented in Tables 5 and 6 it would seem that for germination tests, 200 seeds in a single test would be advisable for ordinary work, the number being increased when desired. It is very important that the probable error be known so that such adjustments may be made.

7. Duplicate tests appear to be of little value as, so long as only the factor of probability in selection is present, variation between duplicates is not significant; if other factors enter, the chances are probably as great that duplicates which vary but little are unreliable. The necessity of making another test must be governed chiefly by judgment, whether duplicates vary or not, and a test of 200 seeds will often require less time and space than two of 100 each.

Comparison with the Results of Rodewald.

As the work of Dr. H. Rodewald came to notice after the present paper was practically completed, it seems desirable to add some extracts showing his results. An abstract of the earlier paper which is a practically complete translation has been published ("G. M. C.," 1897). Rodewald states that errors are either accidental or systematic. A similar statement was made in the beginning of the present paper and in very nearly all of the writer's work an attempt was made

to reduce the systematic errors to a minimum or constant quantity, in order to determine the accidental error.

The data in Table 12, given by Rodewald, were determined by mathematical calculation.

TABLE 12.—*Probable error due to accident.* (Rodewald, 1889, p. 110.)

Percentage of germination.	Percentage of probable error in using					
	100 seeds.	200 seeds.	300 seeds.	400 seeds.	500 seeds.	900 seeds.
95	1.48	1.04	0.85	0.74	0.66	0.49
90	2.03	1.44	1.17	1.02	.91	.68
80	2.71	1.92	1.56	1.36	1.21	.90
70	3.11	2.20	1.79	1.55	1.39	1.04
60	3.32	2.34	1.92	1.66	1.49	1.11
50	3.39	2.40	1.96	1.69	1.52	1.13

Comparing these results with column 1 of Table 2 and with Table 11, they are found to be almost identical, except that the former shows approximately equal values for 80 percent to 50 percent when only two factors are considered. Where the third factor is considered the results conform closely to those given above (indicated in figure 1). Rodewald apparently did not distinguish between these two conditions, nor has he given values for percentages lying between 95 and 100. He found these theoretical values to conform closely with the results from actual tests, but for this he used the results of a number of samples showing approximately the same germination instead of making a large number of tests from one sample.

From several experiments in which results of different laboratories were compared, he found that the systematic error held a rather constant relation to the accidental. From this he finds that the total error is about 2.2 times the accidental error (Rodewald, 1904). From this he derives the following table of variation which should not be exceeded in more than 4.3 percent of comparative tests of 200 seeds each by different laboratories:

For 95% germination, 6.3%; For 70% germination, 14.4%;
For 90% germination, 9.4%; For 65% germination, 15.0%;
For 85% germination, 11.2%; For 60% germination, 15.4%;
For 80% germination, 12.6%; For 55% germination, 15.7%;
For 75% germination, 13.6%; For 50% germination, 15.7%.

For allowable variation between duplicate tests he gives the following, which will still be exceeded in 4.3 percent of the cases (Rodewald, 1889, p. 226):

Percentage of germination.	Allowable variation in each test. Using 200 seeds.	Using 100 seeds.
95	4.62	6.57
90	6.49	9.04
80	7.62	13.06
70	9.78	13.82
60	10.38	14.77
50	10.65	15.08

The variation allowed here between two tests at 80 percent germination is but slightly less than the extreme variation between duplicates shown in Table 6. The extent to which the results of Table 5 exceed such allowance is slightly greater but still within the 4.3 percent limit of accuracy of the table. This is surely a confirmation of the writer's contention that duplicates varying 10 percent, 15 percent, or even more may still be reliable tests.

For purity tests Rodewald considered that an allowance of 2 percent could be used for clover samples having a purity of 90 percent or more, and 3 percent for those below 90 percent, and that similar values might serve for grasses, if the purity is determined by the weight method (Rodewald, 1904, p. 113). The mean and probable error of tests by 23 stations was $97.992 \pm .406$ percent for one sample of red clover, and 70.032 ± 1.288 percent for one of orchard grass. The present writer believes that the space between 90 percent and 100 percent should be further divided, and it should also be borne in mind that the amounts used for purity determination in Rodewald's tests were twice as large as those in current use in the United States.

The writer has quoted thus extensively from this work partly for sake of comparison and partly to give some of the results, as the papers themselves may be relatively inaccessible to many other analysts, as they were to me. My thanks are due to Mr. J. P. Helyar of the New Jersey station and to Mr. Edgar Brown of the U. S. Department of Agriculture for calling my attention to them. Portions of the later paper referring to attempts to reduce the systematic error and comparison of weight and count methods have not been discussed, but it may be well to quote a few statements from the summary:

> For the clover sorts both weight and count methods are about of equal value. For the grasses both have large systematic errors. It would seem that the weight method would be the more easily carried out (p. 113).
>
> The physiological causes for the large systematic errors of germination testing are yet unexplained. It appears that the evaporating conditions play an important role (p. 117).
>
> The large errors of seed testing are not to be sought in the less worthy work of the seed control stations. They are grounded in the nature of the case.

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VEGETATION AS AN INDICATOR OF THE FERTILITY OF SANDY PINE PLAIN SOILS IN NORTHERN WISCONSIN.[1]

T. J. DUNNEWALD.

While making a survey and report on the soils of a proposed Forest Reserve area in northern Wisconsin, it was noticed that the sandy plains soils varied greatly in their ability to produce a second growth of vegetation after the removal of the original pine timber and the many severe fires which succeeded the logging operations.

The most sandy portions where the original timber was sparse or consisted mostly of Norway and Jack pine, with perhaps a few white pines, now bear little or no second growth. Small Jack or Norway pines 6 to 10 feet high appear in clumps and the poplar brush, if any, is also less than 10 feet high, while a thick growth of sweetfern, brakes, blueberries, or coarse bunch grass is the only ground cover, In other places where moisture conditions appeared somewhat better and the soil slightly more loamy, the second growth is often 20 to 40 feet high and consists of poplars, white birch, cherry, alder, and young white pine, with but few Jack or Norway pines. The original timber also had been of a better quality here, being mostly large white and Norway pine, as indicated by the stumps.

In the final correlation of the soils on the basis of their value for agricultural purposes, the most sandy soil was described as being of low value for farming, while the more loamy soil, as indicated by the vegetation and better moisture conditions, was classed as being

[1] Contribution from the Wisconsin State Soil Survey, Madison, Wis. Received for publication April 6, 1917.

of fair value for future farming. Typical samples from widely separated areas of these classes of soil were collected and analyses made to correct or confirm the field interpretation.

Table 1 gives a summary of the various determinations made on these two groups of soil samples.

TABLE 1.—*Chemical and mechanical analyses of sandy pine plain soils bearing good and poor second growth.*

SOILS WITH SPARSE SECOND GROWTH.

Soil No.	Chemical analyses.					Mechanical analyses.							
	P.	K.	N.	Lime requirement.[a]	Moisture equivalent.	Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.	Class of soil.
						Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
919 *A*	0.052	1.24	0.096	2,000	15.3	6.85	22.44	22.20	27.08	46.90	9.61	6.92	Coarse
919 *B*	.035	1.36	.045	500	7.4	9.10	18.43	21.58	37.37	5.42	4.74	3.35	Medium
882 *A*	.052	1.29	.063	2,000	14.8								do.
882 *B*	.041	1.12	.033	2,000	9.8								do.
873 *A*	.051	0.76	.095	2,000	15.0								do.
873 *B*	.031	0.95	.027	500	9.3								do.
861 *A*	.042	1.11	.057	2,000	14.9								do.
861 *B*	.027	.87	.056	2,000	11.5								do.
859 *A*					16.7								Medium to fine
859 *B*					12.0								Fine
743 *A*	.042	1.19	.047	2,000	12.8	2.54	15.79	29.45	28.54	6.84	8.49	5.76	Medium
743 *B*	.029	1.01	.025	500	6.6	4.03	14.57	30.30	31.11	9.87	6.17	4.13	do.

SOILS WITH LARGE SECOND GROWTH.

863 *A*	.059	1.06	.099	2,000	19.9	1.25	4.33	8.40	46.17	21.18	12.37	6.32	Fine
863 *B*	.033	1.18	.049	2,000	13.8	2.00	4.13	9.20	51.01	21.62	7.95	4.18	do.
862 *A*	.041	0.97	.079	2,000	16.5								do.
862 *B*	.032	0.97	.032	2,000	13.5								do.
849 *A*	.047	1.21	.082	2,000	21.9								do.
849 *B*	.037	1.17	.049	2,000	16.7								do.
780 *A*	.058	1.12	.078	2,000	22.9	7.23	20.05	20.82	14.49	8.22	20.98	8.80	Medium
780 *B*	.039	1.31	.037	2,000	15.2								
785 *A*	.068	1.21	.094	5,000	18.4	0.85	11.07	19.04	27.93	27.06	11.26	3.20	Medium to fine
785 *B*	.042	1.15	.028	5,000	12.7	0.80	9.44	18.33	28.51	32.98	7.47	2.64	Medium to fine
741 *A*	.063	0.87	.068	2,000	16.9								Medium to fine
741 *B*	.030	1.08	.026	2,000	10.6								Fine

[a] Lime requirement in pounds of calcium carbonate necessary to neutralize the surface 8 inches of soil.

A mechanical separation of the particles of different sizes of which the soils are composed was made on several of the samples. The results, as will be seen in Table 1, indicate that the soils with small or sparse second growth must be classed as coarse or medium sand,

while those bearing large second growth should be classed as fine sand because they contain larger amounts of the smaller sized soil particles and fewer of those of larger size. The curves in figure 4 show the total average percentages of soil particles of different sizes in the two groups of samples as shown by the mechanical analyses.

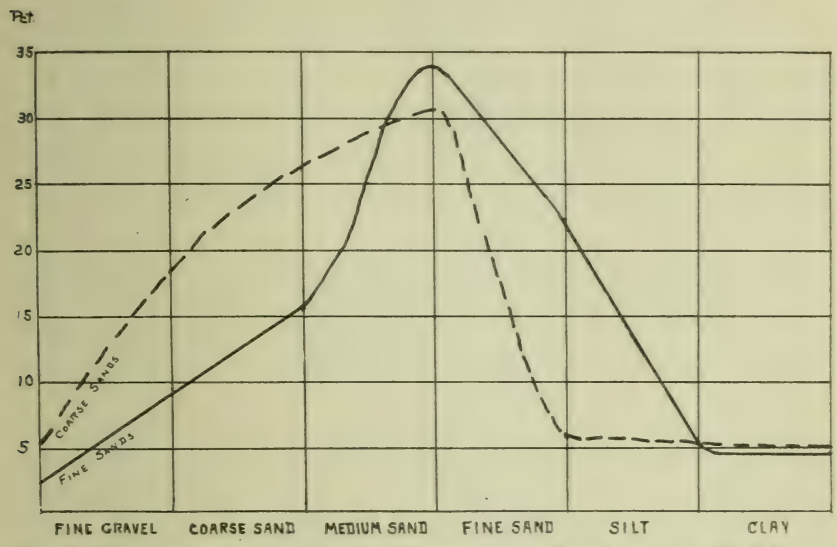

FIG. 4. Graph showing total average percentages of soil particles of different sizes in the two groups of samples (Table 1).

Another arrangement of the percentage in Table 2 indicates the predominance of the finer particles in the soils bearing the best vegetation. It will be seen at a glance that while the content of the finest clay particles is much the same, the silt and especially the finer sands are present in much greater proportion in the soil where the better reproduction is found.

TABLE 2.—*Percentage of silt, clay, and finest sand particles in pine plain soils of northern Wisconsin.*

Sandy soil, stunted vegetation.	Clay.	Silt.	Fine and very fine sand.	Finer soil, large vegetation.	Clay.	Silt.	Fine and very fine sand.
	Percent.	*Percent.*	*Percent.*		*Percent.*	*Percent.*	*Percent.*
919 *A*.....	6.92	9.61	31.77	863 *A*.....	6.32	12.37	67.35
919 *B*.....	3.35	4.74	42.79	863 *B*.....	4.18	7.95	72.63
743 *A*.....	5.76	8.49	35.38	785 *A*.....	3.20	11.26	54.99
743 *B*.....	4.13	6.17	40.98	785 *B*.....	2.64	7.47	61.49
Averages....	5.04	7.25	37.73		4.08	9.76	64.11

Chemical analyses for total phosphorus, nitrogen, potassium, organic matter, and calcium were made on the samples collected. The individual determinations given in Table 1 are averaged for the groups in Table 3.

TABLE 3.—*Percentage of phosphorus, nitrogen, potassium and phosphorus in loamy and fine sands as compared with the coarser sands.*

Portion of soil.	Coarse sands.			Loamy and fine sands.		
	Phosphorus.	Potassium.	Nitrogen.	Phosphorus.	Potassium.	Nitrogen.
	Percent.	*Percent.*	*Percent.*	*Percent.*	*Percent.*	*Percent.*
Surface	0.048	1.12	0.071	0.055	1.05	0.081
Subsoil	0.032	1.06	0.037	0.037	1.13	0.035

The amounts of the plant food elements, phosphorus, potassium, and nitrogen, are low in all these samples as compared with other classes of soil which contain more of the finer soil material, such as clay and silt. The greatest difference between the groups is in the element phosphorus, of which the sandy group have 14 percent less in the surface 8 inches of soil. The element nitrogen is present also in about 14 percent smaller amount in the surface soil of the sandy group than in the loamy soils. Other chemical data not given in the table show that the total calcium is but 0.82 percent in the sandy group and 1.16 percent in the loamy group. Expressed as pounds per acre of soil 8 inches deep the food elements are as shown in Table 4.

TABLE 4.—*Pounds per acre of phosphorus, potassium, and nitrogen in certain Wisconsin soils to a depth of 8 inches.*

Portion of soil.	Low agricultural value.			Fair agricultural value.		
	Phosphorus.	Potassium.	Nitrogen.	Phosphorus.	Potassium.	Nitrogen.
Surface	895	20,280	1,391	1,170	26,400	3,147
Subsoil	642	21,653	685	855	25,530	1,151

The moisture equivalent determination consists briefly in placing equal bulks of the different soils in perforated cups in a centrifuge machine, after they have absorbed all the water they will hold. They are then subjected to a speed of 2,440 revolutions per minute for 40 minutes and the percentage of moisture remaining after treatment is called the moisture equivalent. The determination is intended to give a comparative figure for the moisture-holding capacity of different soils. The averages of the determinations are shown in Table 5.

TABLE 5.—*Average moisture coefficients of sands and of loamy sand soils in northern Wisconsin.*

Portion of soil.	Sands.	Fine and loamy sands.
Surface soil	14.92	19.40
Subsoil	9.48	13.76

The group of finer samples, as will be seen, have 27 percent (nearly one-third) greater capacity for holding moisture than have the sands. The difference is about equally divided between the surface and subsoil. The greater capacity of the surface 8 inches of both groups to hold moisture as compared with their respective subsoils may be attributed to the organic matter accumulated in the surface 2 to 3 inches of soil. This material, derived from the partial decay of vegetation, has a very high water-holding capacity. This greater water-holding capacity is an especially important matter in judging of the crop value of sandy soil and the lack of the larger water-holding capacity often means the loss of crops on the more sandy soils during even short periods of drought.

CONCLUSIONS.

It is concluded that the character and size of the undergrowth of cut-over lands is a safe indicator of the cropping capacity of the soil for agricultural purposes on sandy pine plain lands.

The heavier growth indicates a higher content of plant food, the presence of more fine material in the soil, and especially a greater capacity of the soil to retain moisture and to enable vegetation and future crops to resist periods of drought.

A MECHANICAL EXPLANATION OF PROGRESSIVE CHANGES IN THE PROPORTIONS OF HARD AND SOFT KERNELS IN WHEAT.[1]

GEO. F. FREEMAN.

Soft wheats of low gluten content are usually found in warm humid or irrigated sections. Many of these varieties when taken to drier, colder climates, produce hard, translucent grains having the horny

[1] Contribution from the University of Arizona, Tucson, Ariz. Read for the writer by Dr. R. H. Forbes at the Second Annual Conference of Agronomic Workers in the Eleven Western States at Pullman, Wash., August 2, 1917. Received for publication August 27, 1917.

texture of wheats characteristic of these conditions. Other varieties produce soft, opaque grains in all situations and there are yet other sorts which produce a greater or less percentage of hard, translucent grains even in warm, humid regions.

With reference to their response to environic conditions, Howard, Leake, and Howard[2] separate wheat varieties into three classes, as follows: (1) Wheats which always remain soft, (2) wheats with a tendency to remain hard, and (3) the majority of varieties in which the consistency varies greatly according to the locality and the conditions under which they are grown. An investigator working upon the relative effects of variety and of climate on the quality of wheat might easily be led to serious errors of conclusion should he chance to include in his tests varieties belonging to only one of these classes. Particularly would this error impend should he work only with class 3. It is not to be understood that the three classes here defined have well marked limits. As a matter of fact they grade insensibly into each other through intermediate types. The three classes, therefore, merely distinguish between groups of hereditary tendencies which are more or less marked in their intensity. Hence, we have a field for almost infinite variety in the nature and sensitivity of the response to environment as expressed in the texture and composition of the wheat grain.

As, however, there are varieties which produce a large percentage of hard grains of high protein content even in warm, irrigated sections and as these are qualities constantly sought by the millers, the question arises as to why the wheats of warm humid or irrigated sections are usually of inferior grade. We have no conclusive evidence that there is any noticeable progressive change in the nature of the climatic reactions of a pure race of wheat when brought to a new environment. In view of the fact that hard wheats of high milling quality are often introduced into these localities with a view to improving the quality of the grain produced, why is it that these better varieties so often are either lost or else soon deteriorate to such an extent that they are no better than the ordinary local sorts? The experiments now to be described had for their object the working out of the mechanism by which these better introductions are lost or else gradually deteriorate.

During several years in which the writer has had under observation the wheats grown on the Arizona Agricultural Experiment Station farm at Yuma, he has noticed that commercial varieties of durum

[2] Howard A., Leake, H. M., and Howard, G. C. Memoirs Dept. Agr. India, v. 5, no. 2. 1913.

wheat have shown little or no tendency to gradually become softer from season to season but that both local and introduced commercial varieties of bread wheats are either entirely soft or else show the usual progressive tendency toward becoming soft.

In the spring of 1912 a large number of heads were selected and in the following fall all were sown in head rows. The pure races thus originated represented five types, as follows: White durum, red durum, poulard, red bread, and white bread wheats. All of these wheats were sown within one week's time, but their ripening periods spread out over about a month's time, extending from the middle of May to the middle of June. Hardness was determined by the percentage of clear, translucent grains. No grain was considerd hard if it had even a spot of starchy, opaque endosperm. The different head rows showed practically every percentage of hardness from 0 to 100. Table 1 gives the average yield in grams per 100 feet of row and the

TABLE 1.—*Correlation of yield and percentage of hard grains in various classes of wheat at Yuma, Ariz., in 1914.*

Class.	Number of pure races.	Average yield per 100 feet of row.	Average percentage of hard kernels.	Correlation between yield and percentage of hard grains.
		Grams.		*Percent.*
White durum	264	2,032	77	+ 22 ± 4
Red durum	37	1,481	74	+ 26 ± 9
Poulard	79	1,636	28	− 20 ± 7
Red bread	179	1,505	53	− 38 ± 4
White bread	65	3,131	23	− 52 ± 6

percentage of hard grains in the five principal groups, together with the correlation between the yield and the percentage of hard grains in each group. In Table 2 the different classes are divided into hard and soft groups according to the percentage of hard kernels each

TABLE 2.—*Number of head rows in each class placed in the hard and the soft groups, with range in percentages, average percentages of hard grains, and yield to the 100 feet of row.*

Class.	Number of head rows in class.		Range in percentage of hard grains.		Average yield per 100 feet of row.		Natural tendency under Arizona conditions.
	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.	
			Percent.	*Percent.*	*Grams.*	*Grams.*	
White durum	95	169	5–76	77–100	1,896	2,108	Hard
Red durum	14	23	18–70	74–100	1,434	1,510	do.
Poulard	48	31	0–27	31– 92	1,686	1,560	Soft
White bread	79	100	0–52	53–100	1,788	1,283	do.
Red bread	51	14	4–21	27–100	3,410	2,111	do.

head row contained. In this table the range in percentage and average percentage of hard kernels in each group are given, with the average yield from 100 feet of row.

Table 1 shows that in the white and red durum varieties there is a plus correlation between yield and hardness, whereas in the poulard and white and red bread wheats the correlation between yield and hardness has the minus sign. In other words, among the durum wheats the harder strains on the average produced most; whereas among the poulards and bread wheats the high yielders were softest. As it has been repeatedly shown (Lyon and Keyser,[3] Howard, Leake, and Howard[4] and Le Clerc and Leavitt[5]) that the soft, opaque yellow berries contain less protein than the hard, horny, translucent grains of the same variety, we may safely assume that these harder grained strains also contained a higher nitrogen or protein content than those with a larger percentage of soft kernels. Now, since practically all commercial varieties of wheat are mixtures of slightly different types and since under the given conditions certain strains produce more than others, when these varieties are sown in a given locality for a number of years, a climatic selection will commence whereby the higher yielding strains will gradually come into ascendency. If now these high yielding strains be the softer ones, the harder strains will be slowly eliminated and we shall find the wheat becoming softer.

One hundred and forty-five head selections were made from a commercial variety of Turkey wheat obtained in Kansas. All of these selections were true to the Turkey type of head, habit of growth, and size and character of kernel. The pure races which they produced, however, differed considerably in their yield and in their resistance to the tendency to become soft under Arizona conditions. Thus the percentage of hard grains in the different strains in 1914 varied from 3 to 100 percent; in 1915, from 29 to 100 percent, and in 1916 from 65 to 100 percent. That these differences were varietal and tended to persist in the same strains from year to year is shown by the correlations between these characters from one year to the next, as follows:

[3] Lyon, T. L., and Keyser, A. Winter wheat. Nebr. Agr. Expt. Sta. Bul. 89. 1905.

[4] Loc. cit.

[5] Le Clerc, J. A., and Leavitt, S. Tri-local experiments on the influence of environment on the physical and chemical characteristics of wheat. U. S. Dept. Agr., Jour. Agr. Research, v. 1, no. 4, p. 276–291. 1914.

Percentage of hard grains in 1914 with
percentage of hard grains in 1915 = 57% ± 4%
Percentage of hard grains in 1915 with
percentage of hard grains in 1916 = 33% ± 5%
Yield in 1914 with yield in 1915 = 55% ± 4%
Yield in 1915 with yield in 1916 = 68% ± 3%

The correlation between yield and percentage of hard grains in these 145 races for the three years were as follows:

1914 = — 25% ± 5%
1915 = — 17% ± 5%
1916 = — 25% ± 5%

The meaning of this may be illustrated by a short study of the results in 1914. The 145 strains may be divided into three approximately equal groups and the average percentage of hard grains and the yield of each group calculated as shown in Table 3. If these strains behaved the same each year (as it has been shown that they do), it is easy to see that the harder races will be practically eliminated in a few years.

TABLE 3.—*Correlation between yield and percentage of hard grains in Turkey wheat in 1914.*

Number of races.	Average percentage of hard grains.	Average yield in grams per 100 feet of row.	Percentage of total yield.
54	52	1,989	53
38	59	1,387	27
53	73	744	20

If, for simplicity of calculation, the races are divided into a harder and a softer group based upon their average percentage of hard grains for the three years and the results from mixed planting calculated on the basis of their respective yields the following figures are obtained.

Year.	Crop.	Percentage in softer group.	Percentage in harder group.
0.....	Seed for 1913	52	48
1.....	Crop of 1914 and seed for 1915	55	45
2.....	Crop of 1915 and seed for 1916	59	41
3.....	Crop of 1916 and seed for 1917	65	35

Projecting the results from the average of the past 3 years:

Year.	Crop.	Percentage in softer group.	Percentage in harder group.
4.....	Crop of 1917 and seed for 1918	70	30
5.....	Crop of 1918 and seed for 1919	75	25
6.....	Crop of 1919 and seed for 1920	79	21
7.....	Crop of 1920 and seed for 1921	83	17
8.....	Crop of 1921 and seed for 1922	86	14
9.....	Crop of 1922 and seed for 1923	89	11
10.....	Crop of 1923 and seed for 1924	91	9

The above tabulations shows that the hard group is thus practically eliminated at the end of ten years. The gradual softening of an impure race of wheat can thus be explained as a climatic selection without the necessity of assuming any direct or accumulative influence of the climate upon the hereditary substance itself.

In like manner we can understand why the durum wheats remain hard under Arizona conditions, for here there is a plus correlation between yield and percentage of hard kernels (+ 22 percent). An hereditary distinction between the durum and Turkey wheat is thus brought to light in that the harder strains of Turkey wheat are much reduced in yield whereas in the durum wheats the harder strains are the better yielders. These hereditary distinctions, though not striking in any one season, are sufficient to maintain the hardness of the durum wheat and slowly change the other toward the condition of softness and low nitrogen content usually found among bread wheats which have been grown for a number of years in a warm climate.

To the agriculturist, the economic conclusion is evident. We must discard mixed commercial varieties and grow only pure races of wheat coming originally from a single plant. As it is practically impossible to prevent the mixing of varieties through the custom thrashers on the farm, it is highly important that the seed wheat of the community be maintained in its standard of purity through repeated pedigree selection. This work should be done either by the State or by reputable trained seed breeders and from these the farmer should renew his seed at least every four or five years.

THE GROWTH OF SHEEP SORREL IN CALCAREOUS AND DOLOMITIC MEDIA.[1]

W. H. MacIntire.

The presence of sheep sorrel (*Rumex acetosella*) under field conditions is generally conceded to indicate a distinct need of lime. The thriving growth of this weed on soil known to be poor in lime was responsible for the common belief that the plant grows best in an acid medium. However, it is now known that sorrel will flourish in soil that has been treated with lime; hence the viewpoint, now held most generally, that the plant thrives in acid soils because of lack of competition from those plants which are more sensitive to a low content of the alkali-earthy elements. Recent contributions have been made upon this subject by White[2] and by Pipal.[3]

As confirming the findings of the two articles just mentioned and also as demonstrating the parallel effects of limestone and dolomite, the following brief statement is offered, together with the illustrations in Plate 1. This work was carried out by Dr. J. I. Hardy, now of the Wyoming station, under the direction of the writer. It was a portion of a series of pot-culture experiments which were incorporated in a thesis as a part requirement for the degree of Master of Science during the years 1912–13 and 1913–14.

Twenty 8-inch clay pots were used in the work, ten containing limestone in different percentages and ten containing dolomite in corresponding amounts. The pots were twice treated with asphaltum paint in order practically to eliminate porosity, so that they could be imbedded in the ground and thus insure more uniform and more nearly normal temperature.

Clean river sand and limestone or sand and dolomite constituted the only solid material in each pot. Each of the three materials was sifted through a 1-mm. sieve. Those portions which passed through

[1] Contribution from the University of Tennessee Agricultural Experiment Station, Knoxville, Tenn. Received for publication September 10, 1917.

[2] White, J. W. Concerning the growth and composition of clover and sorrel (*Rumex acetosella*) as influenced by varied amounts of limestone. Ann. Rpt. Pa. Agr. Expt. Sta., 1913–14, p. 46–64. 1914.

[3] Pipal, F. J. Red sorrel and its control. Ind. (Purdue Univ.) Expt. Sta. Bul. 197. 1916.

the 1-mm. sieve but were stopped by the ½-mm. sieve, were taken for the filling of the pots. The media varied from 100 percent limestone or dolomite to none, the difference between the percentage of each stone and 100 percent being represented by sand. The limestone and dolomite percentages were 100, 75, 50, 25, 15, 2.5, 1.0, 0.5, and 0, as shown in Table 1. The densities of the sand and limestones were closely approximate and the aggregate weight and volume of the contents of each pot were practically constant.

The limestone used contained 92 percent $CaCO_3$ and 0.5 percent $MgCO_3$, making a lime-magnesia ratio of 184 to 1, while the dolomite contained approximately 50 percent $CaCO_3$ and 35 percent of $MgCO_3$, or a ratio of 10 to 7. Each pot was supplied with 0.1 percent P_2O_5 in the form of precipitated lime phosphate and thoroughly mixed in the dry. No iron was added, since each of the stones carried impurities of this element. A nutrient stock solution containing potassium sulfate, potassium nitrate, and potassium chloride was used as a source of mineral plant food. Aliquots of this solution were diluted and applied at the time of seeding and at subsequent intervals, according to the needs of the plants. In the two pots containing sand without limestone or dolomite there was of course some calcium present as phosphate and probably some traces in the sand itself; hence, 0.2 percent of precipitated $MgCO_3$ was applied to each of these pots in order that no one of the pots should have lime without magnesium.

Sorrel seed was sown in the limestone pots April 2, 1913. The seed was from the ammonium sulfate plats of the Pennsylvania station and was obtained through the courtesy of Prof. C. F. Noll, of that station. A uniform stand was obtained in each of the limestone pots, but on June 13 the plants had grown only to a height of about an eighth of an inch, though they were apparently in normal condition. In order to bring the growing period within the desired limits, the method of obtaining a stand was modified. The seedlings were removed and eight stolons of equal size were planted in each pot. The plants were harvested September 22, 1913, thus giving a growing period of 101 days. The same procedure was carried out with the dolomite pots, the stolons being planted March 31 and harvested July 8, 1914, giving a growing period of 99 days. The yields from the several pots containing both limestones are given in Table 1 and the plants themselves are shown in Plate 1.

It will be noted that the sorrel in the limestone pots was harvested before the forming of seed, while fructification took place in the dolo-

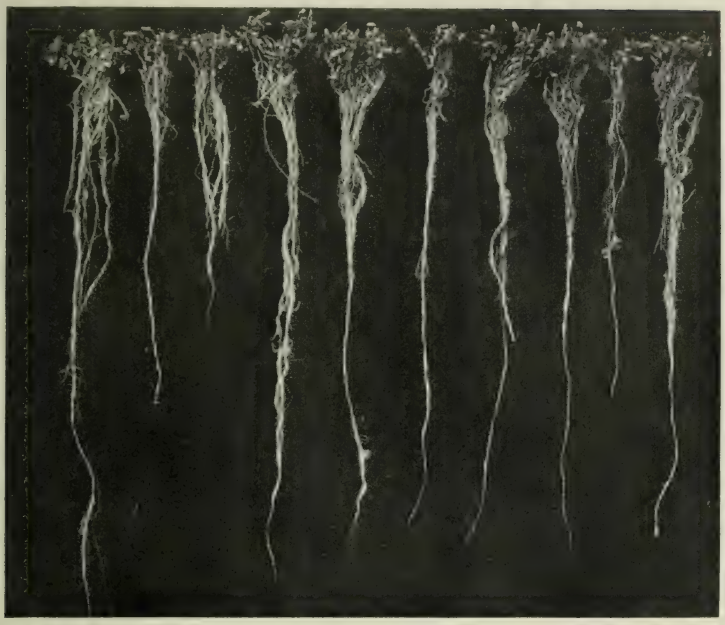

FIG. 1. Growth of sorrel in limestone pots with constant lime-magnesia ratio of 184 to 1. From left to right, the percentage of limestone is 100, 75, 50, 25, 15, 5, 2, 5, 1, 0.5, and 0, the remainder in each case being sand.

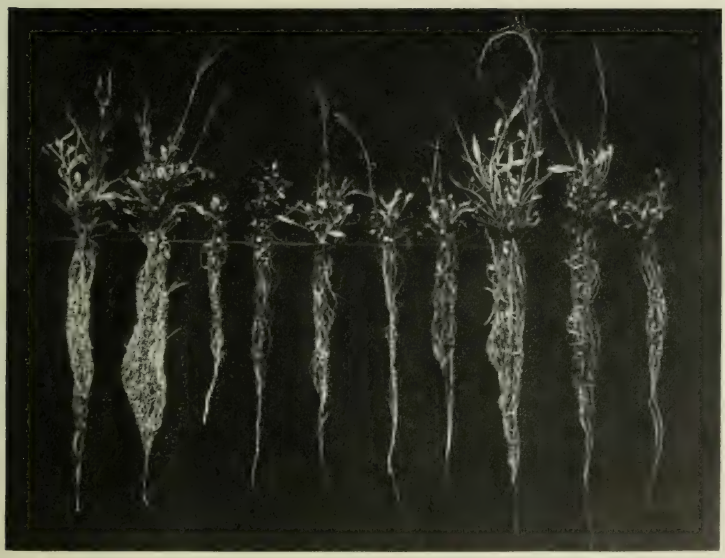

FIG. 2. Growth of sorrel in dolomite pots with a constant lime-magnesia ratio of 10 to 7. From left to right, the percentages of dolomite are 100, 75, 50, 25, 15, 5, 2.5, 1, 0.5, and 0, the remainder in each case being sand.

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mite pots. However, the limestone series was planted and harvested in 1913, while the dolomite series was handled in 1914. In this respect the two sets of pots are not in strict comparison. It is therefore inadvisable to make deductions as to the influence of the CaO-MgO ratios.

TABLE 1.—*Air-dry weight in grams of entire plants of sorrel grown in pots containing varying percentages of limestone and dolomite.*

Pot No.	Limestone series.			Dolomite series.		
	Limestone.	Sand.	Weight of plants.	Dolomite.	Sand.	Weight of plants.
	Percent.	*Percent.*	*Grams.*	*Percent.*	*Percent.*	*Grams.*
1	100.0	0	1.61	100.0	0	3.34
2	75.0	25.0	.42	75.0	25.0	6.54
3	50.0	50.0	1.06	50.0	50.0	1.20
4	25.0	75.0	1.91	25.0	75.0	1.51
5	15.0	85.0	.75	15.0	85.0	1.38
6	5.0	95.0	1.83	5.0	95.0	1.02
7	2.5	97.5	1.48	2.5	97.5	1.57
8	1.0	99.0	1.24	1.0	99.0	3 96
9	.5	99.5	.51	.5	99.5	3.87
10	0	100.0	1.82	0	100.0	1.60
Total.....			10.81			24.39

The results secured demonstrate that the sorrel has no difficulty in maintaining a good growth in strongly alkaline media when not subjected to the intervening influence of clover or other lime-loving plants.

It would seem that the conditions to which the growing plants were subjected in the limestone and dolomite pots are as severe as could be obtained. On the other hand, it is possible that more of the earthy bases might be offered in solution to the plant roots in the case of a fertile soil containing less of lime and more of organic matter; that is, one not so rich in bases but richer in dissolved CO_2. However, this may be in turn offset by the extensive area of contact between roots and limestone the solubility of which is appreciable even in distilled water. As a matter of fact, it was impossible to separate mechanically the roots of the plants from the limestones to an extent which would permit the chemical analysis of the plants as a whole. The heavy root development shown in Plate 1 demonstrates very forcibly that an abundance of the earthy alkali carbonates is in no way inhibitory to the subsurface development of *Rumex acetosella*.

VARIATIONS IN THE DEVELOPMENT OF SECONDARY ROOTLETS IN CEREALS.[1]

E. H. Walworth and L. H. Smith.

In an article appearing in a previous number of this Journal,[2] it was shown that the number of temporary rootlets in cereals, instead of being constant within a given variety, is variable. For example, the author points out that instead of there being a whorl of three temporary rootlets in wheat, according to the usual description given in the literature, the number may be more or less than three and as many as five were noted in some instances. This inconstancy was likewise found to hold true with corn.

Inasmuch as the present writers had an investigation along this line already under way when the above mentioned article appeared and have obtained additional data on this subject, the following observations are presented with the thought that some further information along this line may be of interest. The results are reported of experiments with certain varieties of small grains, including oats, wheat, and barley, with respect to the variations existing in the number of secondary rootlets.

The term "secondary rootlet" is here applied to the temporary roots of the seedling other than the radicle and hence the latter is not included in the data presented. The method followed was to take representative samples consisting of 100 or more kernels from each lot and sow them in pure quartz sand in the greenhouse. The counts were made when the plumules had attained the length of from 1 to 2 inches. The results are set forth in Tables 1 and 2. Table 1 includes a list of some miscellaneous varieties, while Table 2 is made up of several selected strains of wheat and of oats.

In general our observations confirm those of Wiggans, referred to above, in that the number of secondary rootlets is by no means constant for a given variety, but varies among the individuals so that

[1] Contribution from the Plant Breeding Division of the Department of Agronomy, University of Illinois, Urbana, Ill. Received for publication October 13, 1917.

[2] Wiggans, Roy G. The number of temporary roots in cereals. *In* Jour. Amer. Soc. Agron., v. 8, no. 1, p. 31–37. 1916.

TABLE 1.—*Variability of secondary rootlets in different varieties of the small grains.*

OATS.

Variety.	Number sown.	Number germinated.	Number of secondary rootlets.								
			0	1	2	3	4	5	6	7	Mean.
Wisconsin Pedigree No. 1	100	89		3	60	25	1				2.3
White Russian	100	82	1	4	68	8	1				2.0
Mammoth Cluster	100	81	1	10	55	12	3				2.1
Schoenen	100	92		1	50	38	3				2.5
Garton's Victor	200	190		6	160	23	1				2.1
White Bonanza	100	91		4	48	38	1				2.4
Silvermine	100	92		3	51	37	1				2.4
Iowa No. 105	200	176		5	55	115	1				2.6
Big Four	100	90		1	54	35					2.4
Silver Plume	100	77		5	58	12	2				2.1
Black Tartarian	100	88		5	74	8	1				2.1
American Banner	200	191		4	41	116	29	1			2.9
Victory	200	172		4	30	115	21	2			2.9
Lincoln	100	95		1	24	56	14				2.9
Swedish Select	100	97		1	33	54	9				2.7
Siberian	100	98		1	46	41	10				2.6
Irish Victor	100	91		1	40	47	2	1			2.6
Danish White	100	91		1	60	28	2				2.4
Minnesota No. 6	100	94			67	26	1				2.3
Great American	100	95		3	26	65	1				2.7
Sixty Day	200	192		11	121	58	2				2.3

WHEAT.

Red Wave	200	107		1	67	28	10	1			2.5
Beloglina	200	131		7	77	32	15				2.4
Turkey Hybrid 509	300	122			25	31	61	5			2.4
Pesterboden	300	220		4	126	47	43				2.6
Dawson's Golden Chaff	400	179			76	49	33	21			2.9
Turkey	500	419		9	347	49	14				2.2
K. B. 2	200	76		1	58	11	6				2.3
Red Hussar	200	129			95	25	9				2.3
Turkey Hybrid 402	200	90		2	47	29	12				2.6
Red Cross	500	388		9	312	55	12				2.2
Durum	200	83			9	13	60	1			3.6

BARLEY.

Oderbrucker	200	147			1	16	55	65	10		4.5
Wisconsin Pedigree	200	152			3	14	56	66	12	1	4.5
Two-rowed	200	119		3	8	23	46	31	8		4.0
Beardless	200	114			1	15	47	45	5	1	4.4

counts made on a random sample usually give a frequency distribution represented by a fairly normal curve.[3]

In the case of the oats examined, the number of secondary root-

[3] It should be borne in mind that in order to compare our results with those of Wiggans, it is necessary to deduct one from the count in each case to allow for the radicle which was not included in our counts.

TABLE 2.—*Variability of secondary rootlets in pure lines of small grains.*

OATS—PURE LINES.

	Number sown.	Number germinated.	Number of secondary rootlets.				
			1	2	3	4	Mean.
Silvermine 6–403	100	99		42	56	1	2.6
Silvermine 14–383	100	92	2	24	64	2	2.7
Black Gotham 14–173	100	98	1	40	55	2	2.6
Black Gotham 13–332	100	97		23	74		2.8

WHEAT—INDIVIDUAL PLANTS.

Malakoff 1	70	62		61	1		2.0
Malakoff 2	100	91		90	1		2.3
Malakoff 3	100	98	1	95	2		2.0
Malakoff 4	90	81	1	78	2		2.0
Turkey Hybrid 509—1	60	55		37	13	5	2.4
Turkey Hybrid 509—2	100	99		71	20	8	2.4
Turkey Hybrid 509—3	100	99		62	24	13	2.6
Turkey Hybrid 509—4	100	74		32	21	21	2.9

lets ranged from 0 to 5. The table also brings out the fact that the different varieties have their characteristic tendencies toward a higher or lower number as shown by the column of averages. This difference is also very well expressed by the number of greatest frequency, or modal number, which in some varieties is 2 while in others it is 3.

Of the eleven varieties of wheat observed nine of them have the modal number at 2 while in the other two varieties 4 is the number of greatest frequency. This is a rather sharp distinction and it would be highly interesting to know whether any significant correlations exist between this rootlet development and other characteristics of the wheat plant. We hope to pursue this matter in subsequent studies.

The barleys exhibit a tendency toward a higher number of secondary rootlets than possessed by either oats or wheat. Here the maximum number rises to 7, while the modal number varied from 3 in some varieties to 4 in others.

It is interesting to note that in the pure-line selections of oats the range of variability is less than that shown in the ordinary varieties, a result which perhaps might have been anticipated. This also holds true for single plants of wheat, although among the latter those of Turkey Hybrid 509 are slightly more variable than the others, which may possibly be accounted for by their hybrid origin.

In connection with this study a somewhat more extensive series of observations was made in maize where an attempt was made to ascer-

tain whether any correlation exists between the development of these secondary seminal rootlets and the yielding capacity. We hope to have the opportunity of presenting some of these results in a future report.

Summary.

A study of the development of the secondary seminal rootlets in cereals has shown that:

1. The number is not constant, but fluctuates greatly among individuals, variations having been found ranging from 0 to 7.

2. Different varieties of a given cereal show characteristic tendencies in the production of these rootlets.

3. As among the different cereals observed this tendency is greater in barley than in either wheat or oats, as indicated by the varietal averages, modal numbers, and highest extremes.

THE RELATION OF WEED GROWTH TO NITRIC NITROGEN ACCUMULATION IN THE SOIL [1]

L. E. Call and M. C. Sewell

Introduction.

The accepted theory of the effect of tillage upon nitrification has been that tillage increased this biochemical action through a favorable influence upon the principal factors governing nitrification. These factors are the incorporation of organic matter, the distribution of bacterial flora, aeration, and moisture. The writers hope to show in this paper that in the past too much emphasis has been placed on tillage as an agent directly contributing to the formation of nitrates through its effect on the above factors and too little emphasis on it as an indirect means of assisting in the accumulation of nitrates by preventing weeds from using them in their growth.

Review of Literature.

Schlösing and Müntz, Warington, Dehérain (6),[2] and Marquenne (19) were among the earliest investigators to point out the relation

[1] Contribution from the laboratories of the Department of Agronomy (Paper No. 14), Kansas Agricultural Experiment Station, Manhattan, Kans. This paper embodies some of the results obtained in the prosecution of Project No. 18 of the Kansas station. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 12, 1917.

[2] Figures in parentheses refer to "Literature cited," p. 43.

between nitrification and tillage through the incorporation of organic matter in the soil.

The beneficial effect of barnyard manure on crops is common knowledge. That barnyard manure increases nitrification is shown by the recent work of Brown (1), who found that applications of manure up to 16 tons to the acre increased the number of organisms and the ammonifying and nitrifying powers of the soil. He also pointed out the relationship between bacterial activities and crop yields. Temple (18), two years prior to this, published similar results showing an increase of bacterial activities as a result of applications of barnyard manure.

Schlösing (6) advanced the theory that stirring the soil favors the spread of organisms. There are no data today that refute it. We know, however, that the nitrifying bacteria are widely scattered. Müntz and Aubin (6) observed them in many cultivated soils as well as in those of deserts and of high altitudes.

Aeration.

The value of tillage in aerating soils has been recognized since the time of Liebig (14), who pointed out that the decay of organic matter can only take place with a plentiful supply of oxygen, although putrefaction may occur with limited amounts of oxygen present.

Schreiner and Sullivan (17) explained the important rôle of oxidation in the transformation of mineral and organic matter. They pointed out that whatever decreases oxidation in soils tends also to bring about the conditions which decrease growth, and the factors which favor oxidation are the factors which favor soil productivity.

The fact that oxygen is necessary for nitrification does not necessarily imply that an increase in the supply of oxygen will increase nitrification. Leather (11), as a result of recent investigations of the soil gases, states that "it is certain that the diffusion of gases through soils at a depth of 12 to 15 inches is so efficient as to warrant the conclusion that cultivation of the surface soil is unnecessary for purposes of aeration." His investigations showed that even during the wettest weather the volume of gas falls only to 15 or 20 percent of the total soil volume or about half that which is present during long periods of hot, dry weather.

Russell and Appleyard (16) reported results showing but little variation in the composition of atmospheric and soil air.

King and Whitson (10) have presented investigations on the effect

of increasing aeration on nitrification. They bored holes in the soil and determined nitric nitrogen in the surrounding area. There were no data obtained which indicated that nitrification was increased by this manner of aerating the soil.

In a paper on "The Soil Mulch" Call and Sewell (3) showed that nitrification is as great in uncultivated soil (silt loam) free of weeds as in cultivated soil of the same type.

Gainey and Metzler (8) studied the rate of nitrification in a compacted and an uncompacted soil in the laboratory and found greater nitrification in the compacted soil up to the point where the moisture content reached two thirds saturation.

These results show that while oxygen is essential to nitrification, yet sufficient aeration of the soil takes place under most conditions for optimum nitrification without cultivation.

Moisture.

Schlösing (6) observed that the nitrates formed in a soil increased with the moisture content until the moisture was sufficient to interfere with the free passage of air.

Patterson and Scott (15) investigated the influence of soil moisture upon nitrification and concluded that—

1. Nitrification is inactive in soil containing three times more moisture than in its natural air dry condition.
2. For both sandy and clayey soils, optimum amounts of water for nitrification lie within the range of 14 to 18 parts per 100 of dry soil.

Coleman (5) found that nitrification in a loam was most active in the presence of 16 percent of water and was much retarded when the amount of water was reduced to 10 percent or increased to 26 percent.

Lill (12), working with the Marshall silt loam soil, found nitrification active between limits of 5 to 35 percent of moisture. He found two maxima, one at 15 percent and one at 30 percent moisture content.

Hutchinson (9) asserts that in the Pusa soil the optimum moisture content for nitrification is 16 percent and that general bacterial action is intense up to 25 per cent.

Gainey (7), working with a silt loam soil, found an increase of nitrification in loose soil with an increase in moisture up to 30 percent.

The writers have shown in a previous paper (3) that the moisture content of uncultivated soil free of weeds equals that of cultivated soils. Thus cultivation could only effect moisture as a factor influencing nitrification through the control of weed growth.

The results of these investigations indicate that the amount of soil moisture has an important bearing on the rate of nitrification and that the moisture condition most favorable for nitrification is about the same as the optimum condition for plant growth. It is also shown that nitrification may be decidedly active with a moisture content much below the optimum. Some discrepancy in the results reported by different investigations is to be expected, as widely different soils were used.

A review of these investigations as a whole indicate that tillage in its effect on the factors influencing nitrification, particularly in its effect on aeration and moisture, will not account for the difference in nitrates found to exist in farm practice in soil cultivated in different ways.

Experimental Results.

That a marked difference in the nitrate content of soil cultivated in different ways does occur in farm practice is shown by experiments conducted at the Kansas station in which soil has been prepared for wheat in eleven different ways through a period of nine years and in which the moisture and nitrate content of the soil was studied (2). In this experiment wheat was grown continuously and each plot received the same preparation each year. The average yields, the percentage of water available for growth at seeding time, and the amount of nitrates in the soil at seeding time in each plot are given in Table 1.

Table 1.—*Seven-year average yield of wheat, moisture content, and nitrates in parts per million to a depth of 3 feet at the time of fall seeding on 11 plats variously treated.*

Methods of preparation.	Yield per acre.	Moisture available to plant growth.	Nitrates to a depth of 3 feet.
	Bushels.	*Percent.*	*P.p.m.*
Disked at seeding	7.7	4.8	6.7
Plowed Sept. 15, 3 inches deep	13.5	5.6	9.5
Plowed Sept. 15, 7 inches deep	14.8	6.2	7.0
Disked July 15, plowed Sept. 15, 7 inches deep	19.2	6.0	17.6
Plowed Aug. 15, 7 inches deep, and worked as needed	20.7	6.8	17.4
Plowed Aug. 15, 7 inches deep, not worked until Sept. 15	19.1	6.6	16.6
Disked July 15, plowed Aug. 15, 7 inches deep	19.4	6.2	24.2
Plowed July 15, 7 inches deep, and worked as needed	22.0	5.8	25.1
Plowed July 15, 3 inches deep	17.1	5.7	20.7
Listed July 15, ridges worked down	18.5	6.3	23.4
Listed July 15, ridges split Aug. 15	18.2	5.8	21.1

The amount of nitrates in the soil at seeding time and the subse-

quent yield of wheat were much higher in all cases for early plowing or early preparation of the ground. The large difference in yield can not be attributed to a difference in moisture because the moisture content for all plots is nearly the same. There can scarcely be a doubt of the relation between the development of nitrates and yield of wheat. The question then arises of how to account for this large increase in nitrification and yield with early preparation if we accept the conclusions previously presented.

Some additional data bearing on this question have been obtained by the writers in a study of the effect of weeds and of different depths of cultivation on moisture and nitrate accumulations in the soil. In this study there were four plots; one was cultivated 3 inches deep, one 6 inches deep, one was uncultivated but the weeds were removed with a hoe or by hand, and one was uncultivated and the weeds allowed to grow.

As much moisture was found in the plots that were kept free of weeds but not cultivated, taking a 4-year average, as in the plots cultivated 3 or 6 inches deep (3). The nitrates expressed as pounds per acre 3 feet are shown in Table 2. These data represent the average of samples taken monthly from April to October each year.

TABLE 2.—*Annual and average development of nitrates in plots variously treated, expressed in pounds of NO_3 per acre in the upper 3 feet of soil, in the four years from 1914 to 1917, inclusive.*

Treatment.	1914.	1915.	1916.	1917.	Average.	
					1914–16.	1914–17.
Weeds	124.3	42.1	78.5	75.0	81.6	79.9
3-inch mulch	497.8	495.9	246.3	225.3	413.3	366.4
6-inch mulch	550.1	325.2	567.8	No data	481.0	
Bare surface	712.7	643.0	313.3	228.9	556.3	474.5

It is shown that more nitrates were developed in the uncultivated soil kept free of weeds than in the soil cultivated either 3 or 6 inches deep. It is also shown that there is much less nitrate in the soil which produced a growth of weeds than in the soil which did not produce weeds. It is evident that weed growth and not lack of cultivation is the factor responsible for the low nitrate content of the soil which produced weeds.

In 1916 and 1917 the quantity of nitrogen contained in the weeds grown on the weed plots was determined. The amount of nitrogen in the weeds was calculated as nitrates and added to the nitrates present in the soil. These data are assembled in Table 3 and are

compared with the nitrate content of the cultivated and uncultivated (bare) plots.

TABLE 3.—*Nitrogen in weeds expressed as pounds of NO_3 per acre, plus nitrates in the surface 3 feet of soil in October.*

Year.	NO_3 in soil cultivated 3 inches.	NO_3 in soil with bare surface.	NO_3 in soil producing weeds.	Nitrogen in weed growth as NO_3.	Total NO_3 developed in weeds and soil.
1916.....	531.5	445.7	158.3	316.0	474.3
1917.....	372.0	361.2	36.5	322.3	358.8

The last column of Table 3 gives the total amount of nitric nitrogen which must have been produced in the soil growing weeds, providing the weeds assimilated all the nitrogen used in their growth in the nitrate form.[3] These amounts nearly equal the nitrates present in the cultivated or bare surface soils. The estimate of nitric nitrogen in the weed growth is only for that contained in the tops.

Referring again to the plots prepared in different ways for wheat, it will be seen that similar results have been obtained in regard to the effect of weeds upon nitric nitrogen accumulation in the soil. Determinations of the amount of weed growth and their nitrogen content have been made for the past three years on Plot 1, which is unworked throughout the summer and prepared for wheat by disking each season just before the wheat is sown. The nitrate content of the soil of this plot is compared with that of Plot 9, which is plowed 7 inches deep in July and worked throughout the summer. These data are presented in Table 4.

TABLE 4.—*Nitrogen expressed as nitric nitrogen (pounds of NO_3) per acre in weeds and in the surface 3 feet of soil, September determinations.*

Date.	Nitrates in the soil.			Nitrogen expressed as nitric nitrogen in weeds, plot 1.	Nitric nitrogen in plot 1, including that in weeds.	Difference in total nitrates in favor of plot 9.
	Plot 1 disked at seeding.	Plot 9, plowed in July.	Difference in favor of plot 9.			
1915	18.8	127.4	108.6	150	168.8	−41 4
1916	96.2	362.0	265.8	167	263.2	98.8
1917	13.4	186.5	173.1	258	271.4	−84.9

In this case greater nitrification appears to have taken place in the years 1915 and 1917 upon Plot 1 than upon Plot 9, even though it is only the nitrogen in weed tops that has been considered. As an

[3] It is known that plants can assimilate nitrogen in the form of ammonia and in highly organized compounds, but it is not generally believed that they secure much nitrogen in this way under ordinary conditions.

average for the three years Plot 1 shows a higher accumulation than Plot 9.

Further evidence may be obtained from these plots during the season of 1913, a season which was so dry that weeds failed to grow upon Plot 1. This plot is unworked throughout the summer. Table 5 shows the precipitation for July, August, and September and the nitric nitrogen in the soil September 13 and October 10.

TABLE 5.—*Nitrate (pounds of NO_3) per acre to a depth of 3 feet in 1913 on Plot 1 (disked Oct. 1) and on Plot 9 (plowed in July), with the precipitation in July, August, and September.*

Precipitation in inches.			NO_3 in soil September 13.		NO_3 in soil October 10.	
July.	August.	September.	Plot 1.	Plot 9.	Plot 1.	Plot 9.
0.07	0.37	4.89	92.9	76.5	255.5	258.7

The precipitation during July and August was very light and the rains in September occurred after the determinations were made on the 13th. It will be seen that the accumulations of nitric nitrogen in the two plots when the last determinations were made are practically the same. This would tend to show that the small amounts of nitrates found in the soil of Plot 1 in other seasons (Table 1) are due to the fact that the weeds have used this compound in their growth.

Numerous cultivation experiments with corn show that the principal benefit of tillage is the removal of weeds. Cates and Cox (4) tabulated the results of 125 experiments carried on for six years, 1906–1911, in 28 different States. They concluded that cultivation is not beneficial to the corn plant except in the removal of weeds. Mosier and Gustafson (16), as a result of eight years' work, showed that killing weeds without cultivation produced a gain of 17.1 percent or 6.7 bushels per acre over ordinary cultivation (shallow three times).

At the Kansas station similar data regarding the effect of tillage on corn yields are available for the past three years. These results are shown in Table 6.

TABLE 6.—*Annual and average yields of corn on fall-plowed land, variously cultivated, 1914 to 1916, inclusive.*

Cultivation treatment.	Yield per acre, bushels.			
	1914.	1915.	1916.	Average.
Ordinary	13.0	65.0	43.2	40.6
Ordinary and 1 horse cultivator	13.4	62.0	43.2	39.5
Ordinary and 1 horse cultivator every 10 days	11.0	58.8	43.4	37.7
Not cultivated; weeds hoed by hand	9.2	65.0	45.2	39.8

As an average of the three years the uncultivated plots where the weeds were removed produced practically as high yields as the cultivated plots. Apparently there was no advantage from the point of yield in cultivating corn except for the purpose of killing weeds.

Cates and Cox in their report refer to the early work upon the weed factor in cultivation, citing results of Sturtevant at the New York State Station at Geneva in 1886, in Illinois by Morrow and Hunt in 1888 to 1893, in Missouri by Sanborn and Waters in 1889 and 1890, and in South Carolina in 1898 and 1899. Decisive evidence in favor of cultivation was not secured at any of these stations.

If the difference in nitric nitrogen accumulation in cultivated and uncultivated soils is due entirely to the weed growth upon the latter, then the depth of tillage should not affect the development of nitrates. That the depth of cultivation has not greatly affected the accumulation of nitric nitrogen in the soil of the plots prepared in different ways for wheat is shown by the results of the wheat seed bed experiment already discussed in Table 1 and further summarized in Table 7.

TABLE 7.—*Average nitrates per acre in p. p. m. in the surface foot of soils variously treated during the periods of cultivation in the eight years from 1909 to 1916.*

Treatment.	Nitrates as p.p.m. of NO_3 in the surface foot.			
	July.	Aug.	Sept.	Oct.
Disked at seeding	10.3	10.3	7.4	13.7
Double-disked in July, plowed in August 7 inches deep	28.9	31.9	50.6	55.6
Double-disked in July, plowed in September 7 inches deep	24.4	34.1	26.3	42.6
Plowed in August 7 inches deep	18.3	25.9	39.5	38.3
Plowed in July 7 inches deep	18.5	37.8	48.3	50.8
Plowed in July 3 inches deep	18.8	32.4	36.8	44.5
Plowed in September 7 inches deep	23.3	12.7	8.0	16.0
Plowed in September 3 inches deep	17.0	17.0	11.7	21.3

The soil double disked in July, thus preventing weed growth, and plowed 7 inches deep one month later has an equal or even greater nitrate content than the soil plowed 7 inches deep in July. The soil double disked in July and plowed 7 inches in September contains a much greater nitrate content than the soil plowed 7 inches in September without previous disking. The soil plowed 3 inches in September contains a nitrate content equal to that plowed 7 inches at the same date. This effect of depth of tillage is not entirely substantiated by the data on plowing 7 and 3 inches deep in July, as the

former exceeded the latter in nitrate content. However, the average carbon and nitrogen analyses of Plots 9 and 15 may explain this difference in nitrification. The carbon content of the surface 7 inches of Plot 9 has been 1.74 percent; of Plot 15, 1.53 percent. The nitrogen content of Plot 9 has been 0.148 percent; of Plot 15, 0.131 percent. Plot 9 then contained 14 percent more carbon and 13 percent more nitrogen than Plot 15. It seems possible that this difference in the quantity of nitrates liberated in this case may be due to original differences in the soil upon which the work was done.

Summary.

It appears from the data presented that in the past too much emphasis may have been placed on tillage as a direct means of conserving moisture and liberating plant food and too little emphasis on it for the purpose of destroying weeds. If moisture is lost from the soil principally through weed growth and if nitrogen and other elements of plant food become available rapidly in unstirred soil, it is a matter of economy to handle the soil so that weeds may be controlled with the minimum of labor.

It should not be understood that tillage is unessential. It will be necessary to cultivate ground to maintain the proper structural conditions of the soil, to dispose of crop residue on the surface of the soil, to incorporate manures and organic matter in the soil, and to place the soil in suitable condition for seed. Further than this, with the possible exception of heavy types of soil, it is doubtful if tillage is essential where the soil is in a receptive condition to absorb rainfall and where there is no weed growth.

Systems of good farming should be practiced which will assist in controlling weeds, such as a rotation of crops, the use of livestock, especially sheep, for grazing purposes, and timely tillage. By the use of such methods cultivation may be reduced without a corresponding reduction in crop yields.

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ALUMINUM AS A FACTOR INFLUENCING THE EFFECT OF ACID SOILS ON DIFFERENT CROPS.[1]

BURT L. HARTWELL AND F. R. PEMBER.

Attention has been directed by various investigators to the injurious effects arising from the hydrolysis of aluminum salts because of the free acid caused thereby as measured by an increase in the concentration of the hydrogen ions. The entire emphasis has been laid heretofore upon the increase in acidity as the disturbing factor and not upon the aluminum itself.

The Rhode Island station has for a number of years been interested in attempts to ascertain why different kinds of plants varied so remarkably in their response to liming.[2] For example, under the same conditions barley may be increased two to three times by liming and rye receive no benefit whatever. Nevertheless, the authors found that the addition of acid to ordinary nutrient solutions had as depressing an effect upon rye as upon barley seedlings.[3] From this it seemed probable that the toxicity of so-called acid soils was not attributable only to the acid, for in that case the two seedlings should have been affected alike.

Whenever the influence of the various factors which we have studied was the same on the two seedlings we have been disinclined to accept those factors as being very helpful in explaining the varying needs of different crops for lime.

The aqueous extract of an acid soil, like the soil itself, affected the two kinds of seedlings very differently, showing that it contained some ingredient not present in an ordinary nutrient solution.

Sterilization, dialysis, partial distillation, etc., indicated that the substance was crystalloidal in nature. By evaporating the extract,

[1] Contribution No. 240 from the Agricultural Experiment Station of the Rhode Island State College, Kingston, R. I. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Hartwell, Burt L., and Damon, S. C. The comparative effect on different kinds of plants of liming an acid soil. R. I. Agr. Expt. Sta. Bul. 160. 1914.

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igniting, and dissolving the residue in acid, a culture medium was obtained which was much more injurious to barley than to rye.

Aside from the ordinary nutrients the residue was found to contain silicon, aluminum, and chromium; titanium and certain other ingredients which may have been present were not sought. Owing to the presence of considerable aluminum, studies were begun to determine the specific effect of this element by itself and in combination with silicon, chromium, and other substances.

Although the work had to be interrupted frequently, the cumulative impression caused by the results led to a disinclination to accept acidity as the only, or perhaps the main toxic factor influencing the growth of plants on acid soils.[4]

When c.p. aluminum sulfate about equivalent to the amount of aluminum found in the soil extract was used in nutrient solutions the barley seedlings were depressed much more than the rye, but when the same amount of sulfuric acid unaccompanied by the aluminum was present the rye was depressed as much as the barley.

The hydrolysis of the aluminum sulfate was sufficient to give only about one fourth the concentration of hydrogen ions as that resulting from the equivalent amount of free acid. It seems therefore that aluminum must have been the main cause of the depression in the growth of barley and that its effect on rye was much less. In other words, the two seedlings were affected differently by the nutrient solution containing aluminum, the same as they were by the aqueous extract of an acid soil.

If aluminum as such is an important factor to be considered in connection with the deleterious effect of acid soils, any treatment which renders it less active will prove beneficial. It seemed reasonable that a thorough treatment of the soil with a soluble phosphate might accomplish this object. A moist acid soil upon which most kinds of plants were unable to exist was kept intimately mixed for about two weeks with acid phosphate added at the extraordinary rate of 28 tons per acre, after which lettuce was planted. This crop could not exist in the unphosphated soil supplied only with nutrients, but the soil treated with the acid phosphate produced a maximum crop, even more than when lime replaced the phosphate.

It was shown that for a considerable time at least the large amount

[4] Hartwell, Burt L., and Damon, S. C. Loc. cit., p. 416. *Also* Hartwell, Burt L. Twenty-eighth annual report of the Director of the Agricultural Experiment Station. *In* Report of the Board of Managers, Bul. R. I. State College, vol. 11, no. 4, p. 28. Feb., 1916.

of acid phosphate greatly increased the acidity, and yet a crop which usually responds markedly to liming had made its maximum growth on a very acid soil without the addition of any lime. The solubility of the aluminum in dilute acetic and carbonic acids had been markedly reduced by the phosphate, just as it doubtless would be by lime or by a mixture of the two.

Determinations of the amount of what may be called active aluminum may prove to be as desirable as acidity determinations, and the lime requirements of a soil may be due to the need for lime to precipitate toxic aluminum quite as much as to neutralize soil acidity. In fact, the authors found that after sufficient hydrated lime had been added to produce a maximum crop of lettuce a lime requirement equivalent to from 4,000 to 5,000 pounds of calcium oxid per acre, according to a procedure yielding results similar to the Veitch method, still existed at the end of the vegetation experiment, in spite of the fact that nearly all the lime had entered into reaction with the soil. Many instances might be cited for the economic application of acid phosphate apparently in excess of its need for nutrient purposes.

The details of the work upon which are based the ideas here presented will be published in other connections, but it is hoped at this time to interest agronomists in the application of the results to their problems.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the November number was 653. Since that time 6 new members have been added and 1 has been reinstated, while 6 have resigned and 1 not previously reported has been dropped for nonpayment of 1916 dues. The membership therefore remains at 653. The names and addresses of the new members and of the reinstated member, the names of those who have resigned or lapsed, and such changes of address as have come to the notice of the Secretary are given below.

New Members.

Alexander, L. L., Farm Crops Dept., College of Agr., Columbia, Mo.
Freeman, H. A., Central Expt. Farm, Ottawa, Ontario, Canada.
French, W. L., 1221 Laramie St., Manhattan, Kans.
Hagy, F. S., 924 Fremont St., Manhattan, Kans.
Kan, T. T., Box 95, College Station, Texas.
Stadler, L. J., Farm Crops Dept., College of Agr., Columbia, Mo.

Member Reinstated.

Garren, Geo. M., College of Agriculture, Raleigh, N. C.

MEMBERS RESIGNED.

JOHN B. ABBOTT, JAMES M. BELL, MARTIN NELSON,
ELMER D. BALL, GEO. F. CORSON, M. H. YOUNG.

MEMBER LAPSED.

JENS OLSEN.

CHANGES OF ADDRESS.

BABCOCK, F. RAY, Crosby, N. Dak.
BINFORD, E. E., Stephenville, Texas.
CHAPMAN, JAMES E., Granada, Minn.
CRON, A. B., Box 1214, Amarillo, Texas.
DOUGALL, ROBERT, The Davenport, 17 Kellogg Ave., Amherst, Mass.
DU BUISSON, J. P., University of Stellenbosch, Stellenbosch, South Africa.
FRANK, W. L., Bureau of Markets, U. S. Dept. Agr., Washington, D. C.
HILL, W. H., Lab. Inland Rev. Dept., 249 Hastings St., E., Vancouver, B. C.
MACFARLANE, WALLACE, 55 S Street, Salt Lake City, Utah.
MYER, D. S., Extension Div., Purdue Univ., La Fayette, Ind.
NEVIN, L. B., 433 Seventh St., Hollister, Cal.
PACKARD, WALTER E., Extension Div., Agr. College, Berkeley, Cal.
PENDLETON, ROBERT L., Agr. Dept., Ewing Christian College, Allahabad, India.
SHANTZ, H. L., Chula Vista, Cal.
STOKES, W. E., County Agent, Edgefield, S. C.
TAGGART, J. G., School of Agr., Olds, Alta., Canada.
VOORHEES, JOHN H., Agr. Lime Bureau, 503 Riggs Bldg., Washington, D. C.
WHEELER, H. J., 111 Grant Avenue, Newton Centre, Mass.
WYATT, F. A., 216 Agr. Bldg., Urbana, Ill.

NOTES AND NEWS.

C. H. Bailey has resumed his work in cereal chemistry at the Minnesota station after a year's leave of absence, during which he was in charge of the laboratory of the Minnesota Grain Inspection Department at Minneapolis.

Ross L. Bancroft has been advanced from assistant professor to associate professor of soil fertility at Iowa State College.

T. P. Cooper, for the past several years dean of the North Dakota College of Agriculture and director of the station, has been elected to a similar position in the University of Kentucky and entered on his duties there January 1.

J. E. Chapman has been appointed instructor in soils at the Minnesota college and station.

Walter F. Clark, of the department of political science of the College of the City of New York, has been appointed president of the University of Nevada and has entered on his new duties.

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CROP CENTERS OF THE UNITED STATES.[1]

ADOLPH E. WALLER.[2]

THE RELATION OF VEGETATION TO EVAPORATION AND RAINFALL.

The geographic distribution of our important crop plants appears on investigation to be in accord with the well-known centers of natural vegetation. Attention has been called (Transeau, 1905)[3] to the separation and restriction of groups of plants to regions where the combination of factors most suited to the development of the group was localized. Transeau was able to show this by a map of the rainfall evaporation ratios computed from data on evaporation from a free water surface (Russell, 1888) and the known precipitation for the same station. The ratio is an attempt to combine moisture and temperature data as related to plant growth into a single significant figure. His mapped results clearly indicate the desert region, the plains, the prairies and their eastern extension in Illinois, as well as the forest types of the East, namely, the central deciduous, the northeastern evergreen, the southeastern evergreen, and the insular tropical. Had Russell's evaporation data been more complete the ratios for the whole country could have been presented.

As it is, the map (fig. 5) makes an acceptable working basis for outlining the vegetation of the North American continent and re-

[1] Contribution 99 from the Botanical Laboratory of the Ohio State University, Columbus, Ohio. Received for publication August 7, 1917.

[2] The writer acknowledges with much pleasure the advice and assistance given him by Dr. E. N. Transeau during the preparation of this paper, which is a preliminary part of work being carried on under his direction.

[3] References are to "Literature cited," p. 81.

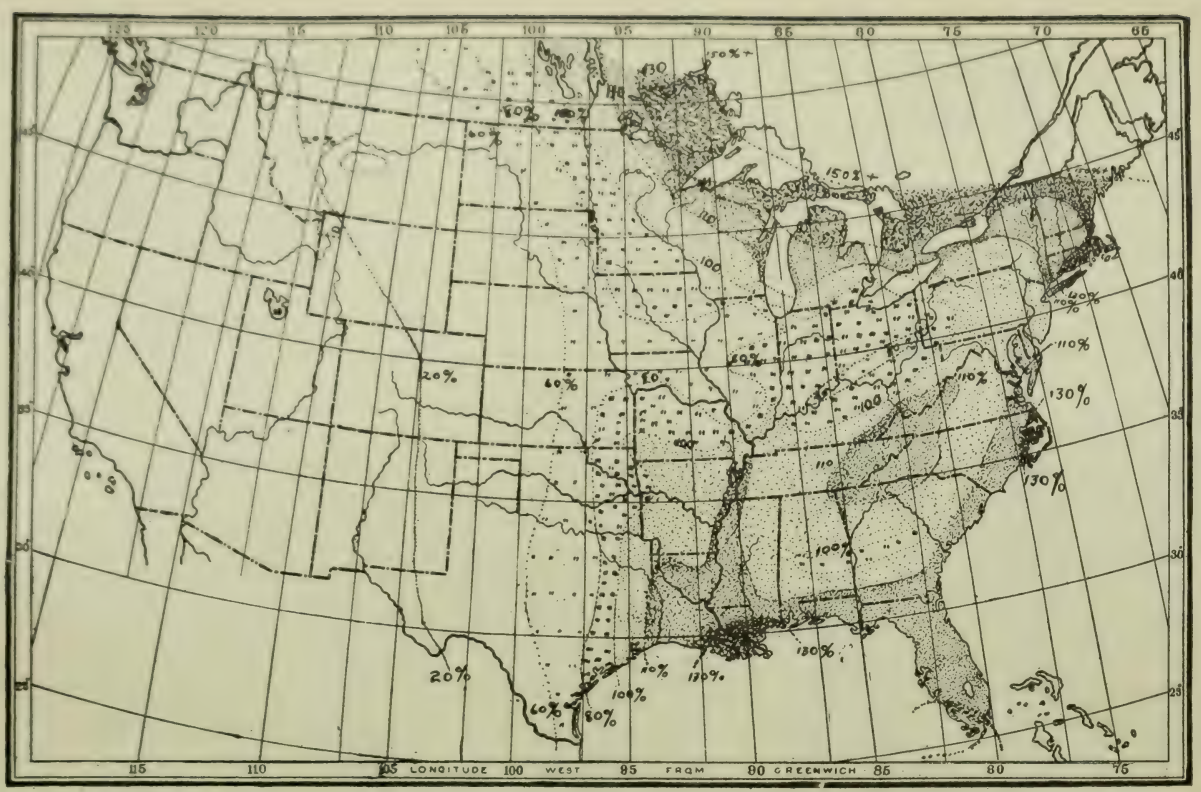


FIG. 5. The ratio of rainfall to evaporation expressed in percentages. Data for the Pacific Coast are not available. The desert lies west of the 20 percent line, the grasslands from the 20 percent to the 60 percent line, the prairies and their eastward extensions between the 60 percent and the 80 percent lines. Where the ratio is greater than 1 there are forests. After Transeau, with slight modification.

mains still the best climatic chart that has been published on forest and prairie distribution. In spite of the discrepancy between rainfall and the amount of water available for plants and between the evaporation and transpiration, the map serves as an effective means for visualizing the distribution of the vegetation.

A number of attempts have been made to correlate plant growth with data gathered by the United States Weather Bureau. The evaporation studies made by this bureau are not, however, of much help to students of plant distribution, either agriculturists or ecologists. Since evaporation and transpiration can be so conveniently used to summarize plant activities, we can go so far as to say that the data of the Weather Bureau are only in the most general way of importance to ecologists.

To improve this situation, Livingston (1915), in a paper read during the Columbus meeting of the American Association for the Advancement of Science, suggested that the rainfall be measured in the usual way, but the evaporation be found by the use of standardized atmometers and the Lehanbauer method be used to find the index of temperature efficiency. By multiplying the rainfall-evaporation ratio by the physiological temperature index, a single figure representing the true climatic summation, namely, the moisture-temperature index, could be obtained. This suggested method also would avoid the inaccuracies of Transeau's chart. However, it has not yet become possible to obtain the results from this suggestion. The figures collected by Russell are still the most complete data available on the depth of evaporation.

In measuring depth of evaporation three factors profoundly affecting plant life are involved:

a, The temperature of the evaporating surface;
b, The velocity of the wind; and
c, The relative humidity.

The rainfall-evaporation ratio, as it combines also the total precipitation with those three, might be expected to agree closely with the actual occurrence of the known vegetational types of the country. This has been found to be the case. The similarities between figure 5 and Sargent's (1884) map of the forests of North America are striking.

A 110-percent rainfall-evaporation ratio, an amount that marks one of the boundaries of the northeastern evergreen forest, means that the evaporation called for is exceeded 1.1 times by the total

annual precipitation. A 20-percent ratio means that the precipitation is only two tenths of the evaporation called for from a free evaporating surface. Only plants with a marked ability to conserve water can exist in the face of such severe conditions for plant growth as is found in regions where the rainfall is so inadequate.

It is interesting to note the geographic significance and particularly the direction of the evaporation lines drawn through stations of the same ratio. In the Great Plains region in the vicinity of the 100th meridian a strong north and south tendency is evidenced. This indicates that in spite of the increase in temperature southward the ratio does not vary with the latitude. There is also an increase in precipitation. The irregularities in the direction of the lines developing farther eastward are due to the proximity of large water areas, e. g., the Great Lakes, the Gulf of Mexico, and the Atlantic, and also to the direction of the winds bearing moisture from these reservoirs of the eastern United States. To a limited extent topography is also a factor. In charts showing the mean monthly and the annual relative humidity, Johnson (1906) displays a distortion in the humidity lines similar to that which appears here in the rainfall-evaporation ratios.

Climatic Origins.

The antecedents of climatic variation are chiefly differences in the latitude, in the unequal warming of land and water areas, the elevation above sea level, and the direction and intensity of the prevailing winds as controlled by the occurrence and movement of anticyclones and cyclones. The differences in latitude classify those parts of the world which are unlike with respect to the angle at which the sun's rays strike the earth's surface. The amount of heat received and the length of the seasons depends upon the latitude. If this were the only consideration and there were no surface factors to react on the atmosphere, it would be only a simple matter to divide the earth into climatic zones.

The difference in the specific heat of land and water, by which the rate of heat absorption and radiation of land and water areas is determined, is an important factor in establishing climate. This difference serves to divide climates into two principal classes, continental and oceanic. The sea takes up heat and gives it off again only one fourth as fast as the land. Climates that are influenced dominantly by the sea or large bodies of water have moderate temperature changes between night and day and between winter and

summer. The oceanic type of climate is in other words equable. Inland, however, where the land absorbs heat and again radiates it three times faster than water does, the temperature changes between day and night and between winter and summer are relatively rapid. Therefore, a variable or continental climate dominates. Since North America, next to Asia, contains the largest land mass, a vast territory in the United States lying between the Rocky Mountains and the 100th meridian possesses a severe continental climate.

The greater the elevation above sea level the more rigorous the conditions for plant growth because of (*a*) lower temperature in summer and winter, (*b*) a drier atmosphere, accelerating evaporation, and (*c*) greater wind velocity. As compensation for these, there are two conditions favoring plant growth, (*a*) greater sunshine intensity and, much more important, (*b*) greater rain and snowfall on the windward slopes. The heavier precipitation is due to the expansion of air as it is forced upward over the sides and summits of mountains in the paths of prevailing winds. On expanding, the air cools and the moisture it contains is condensed. Thus, the mountain sides receive more abundant downpours of rain than the adjacent lowlands. This effect of elevation is markedly evident in the Pacific Northwest coast region where the annual precipitation is more than 100 inches, the heaviest in the United States. The southeast slopes of the Appalachians also have a somewhat greater annual precipitation than the northwest slopes.

The most noteworthy feature of the mountain ranges in America is their north and south trend across the paths of the prevailing winds. The lines of equal rainfall from the Rocky Mountains eastward to the Great Plains are approximately north and south. In the Southern States east of Texas equal rainfall lines follow the general outlines of the Gulf Coast. In the Middle West and eastward to the Atlantic Ocean they are a complex of the combined effects of the Great Lakes, the Gulf, the Atlantic, and the reprecipitated moisture from the forests of eastern America. This last source of moisture for the prairies will be more fully discussed subsequently. The effect of the Appalachians on the rainfall of the territory lying between them and the source of water is much less apparent and also less direct than the effect of the western mountain systems.

The next factors to be considered are the centers of action produced by the large areas of permanent high and low barometric

pressure. While all the permanent centers of action of the world have some effect on the climate of North America only five of these are shown in the accompanying diagram (fig. 6). For the purposes

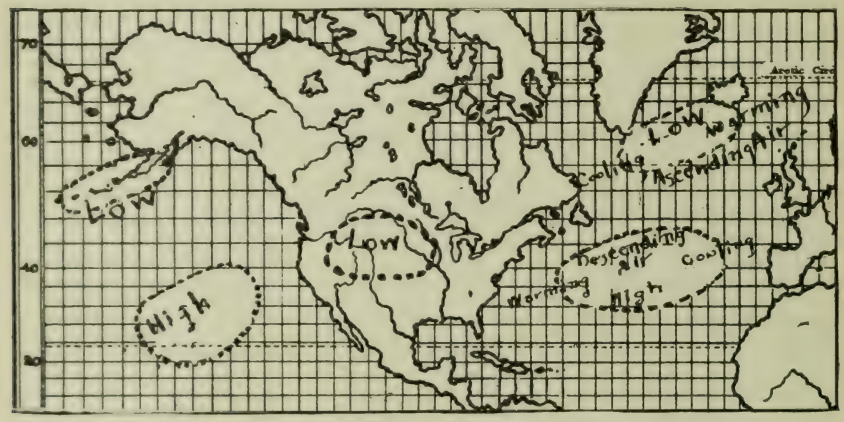


FIG. 6. Diagram of the permanent centers of influence of high and low barometric pressure in the vicinity of North America. The interplay of these and their effect upon the evaporating power of the air and on summer climatic conditions is indicated.

of this paper it is sufficient to consider their operation in summer only, not in winter. Interaction of two kinds is to be considered. The first is the interaction between the anticyclones and the cyclones themselves. In addition, within one given area of action the opposite extremes have reciprocal effects. The eastern side of a high and the western side of a low are regions of ascending, converging, cooling air. This is a region of increasing moisture. The western side of a high and the eastern side of a low are regions of descending, diverging, warming, drying air.

It will be noticed that four of these permanent centers of action are at sea and only one on the continent. While they are said to be permanent this does not mean that they are stable. As a matter of fact they are constantly moving back and forth. If the continental low should shift eastward, or if the western side of the Atlantic high should encroach on the Atlantic coast, the effect on all the area east of the 100th meridian would be the same. Drying, clearing air would descend over the whole region, flowing either from the northwest where the low exists, or from the northeast where the influence of the high is manifested. These two permanent centers of action are the most important in their influence on summer

weather conditions of the greatest part of the United States. If the action of these centers should be just the converse of what has been described, i. e., if the Atlantic high did not encroach westward and the continental low remained in the far north, warm, moist weather conditions would prevail. The effect of these centers on the crops of eastern America is thus plain. If the drying, clearing air conditions lasted a long enough time, a drought and poor crops would result. If these conditions do not exist, then the prevailing winds are from the south and southwest. These, having blown over the reservoirs of the Gulf and the Atlantic, carry in moisture, which is precipitated as the air converges and ascends.

The combined action of differences in latitude, difference in the specific heat of land and water, elevation, and anticyclone and cyclone movements produce in the United States three distinct climates. The first is of the narrow strip of territory from the Pacific Coast to the mountains, an ocean type of climate purely. The second is of the upland plateau from the mountains eastward to the 100th meridian. In the intermountain basins the climatic conditions are locally modified by the presence of water, especially northward, but over by far the greatest part of the region a changeable, continental climate dominates. The third division is from the 100th meridian where a continental climate prevails, to the Atlantic where conditions are influenced dominantly by the ocean. The change is gradual from one type to the other.

On the coastal plains everywhere there are regions of rich, abundant vegetation. This is directly related to the climate, the vegetation being a response to the presence of large amounts of moisture. Climate is also the cause of the Great Plains, with their sparse vegetation and dry, shifting soils. The prairie may be regarded as a transition from the forest conditions of the East to the arid conditions of the central plains. Climate is responsible for the origin of the prairies, but we must look to other factors to explain their persistence. The more abundant moisture of the prairies as compared with the plains has been attributed by Zon (1913), to the forests of the southeastern United States. In his opinion land evaporation is more important than has usually been considered. Moisture does not take a single flight inland from the water areas, but is precipitated and re-evaporated in a series of short flights. The forests, utilizing the water in their own growth, again evaporate the larger portion of it, acting as a temporary deposit bank from which

the moisture may be drawn into the air and redistributed for the use of plants in the path of this moisture-laden atmosphere. His argument has three steps: First, the coincidence of precipitation in eastern United States and the prevailing southerly winds. The cause of the direction of the winds has already been indicated. Second, evaporation from the land constitutes seven-ninths of the total precipitation, while evaporation from the oceans is only two-ninths. Third, a cover of vegetation offers a better evaporating surface than a body of water and a forest evaporates more water than any less dense vegetative cover. There is abundant proof for each of these premises and one is compelled to accept the conclusion that the forests are an important factor in determining the humidity of the prairies.

To say that there is more abundant moisture in the prairies than in the plains is only another way of saying that there is more abundant vegetation. Many plant geographers, including Pound and Clements (1898), C. E. Bessey (1897), Shimek (1911), Gleason (1912), Vestal (1914), and others, indicate or actually state that the forest is migrating across the prairie. If, then, the eastern prairie region is climatically a potential deciduous forest, it appears that the eastern forests in their spread can become moisture bearers and therefore equalizers of climatic conditions farther and farther west. As the lands growing cultivated crops are, next to the forests, the most efficient evaporators, the intensive use of the level lands and the careful forestation of the parts not adapted to cultivation in these eastern States may make large areas of the country far inland from the primary sources of moisture more productive than has hitherto been imagined. The examination of the diminishing prairie areas in Ohio will doubtless throw light on this important problem.

Climatic and Edaphic Factors.

The natural successions of plant associations in a given region have been recognized for a long time. Cowles (1901) was the first to show that plant successions may be correlated with the physiographic development of a locality. Soil structure, the water-holding capacity of the soil, and the slope of the land are determined by historic and present physiographic changes.

Although we now know that other physical factors independent of the physiography are steps in the plant succession, nevertheless full credit must be given to Cowles for presenting so stimulating a view

as the physiographic one for the first systematized studies on plant successions.

In every stage of their development plants respond to the moisture and temperature changes of the habitat. The nature of the soil has such a far-reaching influence upon plant life that it must be considered second in importance to but one factor, the climate. Those plant growth factors related to the soil have been named by Schimper (1903) the edaphic factors.

Warming (1909), impressed with the fundamental relation between plant growth and available water supply of the habitat, grouped vegetation into three principal classes, hydrophytes, mesophytes, and xerophytes. The water content of soils was made the basis of his work, but when he recently reclassified the three types in order to accommodate them more closely to plant distribution, the new system was too involved to receive general recognition from plant geographers. Schimper made practically the same grouping that Warming made of water-content associations. He also pointed out that the terms forest, grassland, and desert are a subconscious classification of the principal climatic formations and are only another way of expressing the water content of soils.

The effect of the edaphic factors is to modify the climatic influences. The physical and chemical properties of soils tend to diminish or intensify the effect of climatic factors upon plant growth. Thus we might see in regions of moist climate rock faces, cliffs, or sand dunes in which desert conditions would be approached. Xerophytes, those plants physiologically adjusted to drought conditions, would be able to occupy and hold these situations as long as conditions remained little suited for the growth of plants requiring more moisture.

The physical nature of soil structure is more important to plant life than the chemical composition of the soils, due to the relation between soil texture and water content. An illustration of the importance of the structure of the soil is seen in the well-known observation that the plant successions on clay and on sandy soils are the same, but in sand require a much longer time to complete the cycles. It should be stated that although there are observations and records of soil experimentation carried on by careful agriculturists for more than one hundred years, yet much less is known about the soils and their effects upon plant life than has been learned of the climatic factor.

The influence of glaciation in destroying topography of former times and mixing the soils must be pointed out as important to plant

successions and to crops. In the regions of severe glaciation there is a widespread homogeneity and locally extreme heterogeneity of the soil. Plant successions in these regions are quickly identified. Primary successions proceed regularly enough until the climax formation, the maple-beech or the mixed mesophytic forest, is reached. Secondary successions are readily recognized and these also proceed toward the climax. In regions where there was but little leveling and mixing of the soil as the result of glacial action, pioneer stages more difficult to arrange in succession are frequently met. Regions such as those where Fernald (1907) recorded observations on the soil preferences of certain alpine plants come under this distinction. In older, rougher landscapes in the unglaciated southeastern United States investigations conducted by Harper (1914–1917) report the plant formations restricted to areas of different soil classes. The great local diversity of the vegetation led Fernald to classify plants upon a supposed preference for soils of different compositions (based on an analysis of the rock origins only), and Harper to correlate plant distribution with soil types.

In all probability, however, the edaphic factors interfere with the completion of the successional cycles. It is also likely that temporary climaxes have been mistaken for permanent responses. If in the southeast, for example, pines are found on sandy and deciduous trees on clay soils it should not be supposed that there is an inherent preference of pines for sand and oaks for clay. Rather, it is reasonable to believe that the high rate of evaporation and the high rate of humus oxidation known throughout the entire southeast and intensified on sandy soils are factors tending to make the temporary climax of pines persist for a long time. The climax type of vegetation, then, would be composed of evergreens and a large percentage of invaders from the deciduous center, since the latter can make more efficient use of the light and can offer stronger competition for the better soils. Fuller (1914), working in the Lake Michigan sand dunes, has brought out graphically the importance of vegetation in modifying the habitat by the accumulation of humus. He shows by many charts the changes in the transpiration rates which result. Similar studies in the southeastern center, with simultaneous studies on the retardation of humus accumulation due to rapid oxidation, would be interesting and profitable.

The difference in the total annual rainfall and the evaporation in the eastern prairies and the deciduous center is not in itself sufficient to account for the great difference in the vegetational aspects. But

the better distribution of the moisture throughout the year produces the forests of the East, while the intermittent moisture and long drought causes grass to be the dominant type of vegetation of the Middle West. The climatic change is gradual from the 60-percent evaporation line eastward. The continuance of the prairie therefore is largely dependent upon edaphic conditions. Poor soil drainage and the accumulation of muck in the soils seem responsible for the black prairie lands. The prairie peninsula (see fig. 5) lies extended across Illinois to Indiana because of situations unfavorable to drainage and oxidation. Scattered through the glaciated portions of Indiana and Ohio are also small areas of typical prairie. In all of these, until drained and broken, big bluestem (*Andropogon furcatus*), one of the bunch grasses typical of the prairies, can be found.

The plains are more arid than the western part of the prairies and much drier than the eastern part. They lie west of the 60-percent evaporation line. Short grass, a climax association of Bulbilis-Bouteloua, dominates. Just as edaphic prairies are found in the deciduous forest climax, so are edaphic plains in the prairie climax. Gleason (1910) has demonstrated this in the sand deposits of the Illinois River. These deposits date from early post-glacial times when the carrying power of the river was severely overtaxed. Blowouts, common in the sand hills of Nebraska, and the same plant successions proceeding from these wind-eroded, bare areas are reported.

It is interesting to see how climatic and edaphic factors, though independent of one another, can sometimes make the same agricultural practises necessary. An example of this can be noted in the custom of furrow planting in the sand plain near Havana, Ill., an edaphic plains situation, and in western Kansas, the climatic plains. In both of these places grains and seeds are dropped into a deep furrow in order to be as near to the water table as possible. As the plants grow, the hills on either side of the furrow are leveled toward it until by the end of the growing season the plants are standing in hills. It is also significant to know that the cactus, *Opuntia rafinesquii,* is the common weed of the cornfields in these sand areas.

The Vegetation Centers.

From what has been given it can be seen that the forest centers are understood to mean those regions in which the combined operation of all the climatic and edaphic factors still leaves an environment suited to the most favorable development of the species included in the local vegetation type. For example the white pine, *Pinus*

strobus, the black spruce, *Picea mariana*, the hemlock, *Tsuga canadensis*, the balsam fir, *Abies balsamea*, and the paper-bark birch, *Betula papyrifera*, are several trees belonging to the northeastern center. A corresponding list of characteristically dominant trees for the central deciduous center would include the sugar maple, *Acer saccharum*, the beech, *Fagus americana*, the chestnut, *Castanea dentata*, the white oak, *Quercus alba*, and the tulip tree, *Liriodendron tulipifera*; while for the southeastern center the loblolly, *Pinus taeda*, the long-leaf pine, *Pinus palustris*, the sweet bay, *Magnolia glauca*, the bald cypress, *Taxodium distichum*, and the yellow pine, *Pinus echinata*, might be chosen. Whether investigators would agree on these trees as characteristic of the different centers does not so much matter as the point that for each forest center there would be a group of trees of different physiological requirements. In the same way the lists of the dominant vegetation of the plains, the prairies, and the desert would possess marked physiological individuality. Dominance in the sparsely vegetated regions does not carry the sense of having successfully competed with other plants always, but we can speak of dominance because the endemic plants have conquered the environment where so many others failed.

In addition to dominance, Adams (1902 and 1909) has pointed out maximum size, greatest differentiation of type, and widest range of habitat as other criteria of centers of distribution. It is not to be inferred that the center of distribution is necessarily a place from which the species is spreading. Rather it is implied that here the optimum climatic factors are localized and as one leaves a center conditions become less than optimum. Therefore those species which are most completely dependent upon definite conditions are gradually eliminated.

The centers of vegetation are as strongly differentiated by crops as by the native forest trees. Timothy, spring wheat, rye, buckwheat, and potatoes occupy the same region as is marked by the first group of trees; corn, winter wheat, oats, red clover, and beans dominate the central region; while cotton, tobacco, yams, cowpeas, and peanuts center in the southeast. The same criteria applied above for the forest centers hold for the crop centers. The first evidence that we are approaching the center for a given crop is in the number of farms on which it is being grown. The next is that even the rough, hilly, and relatively poor lands produce a fair yield. Then it will be noticed that more varieties of this plant are known and that individuals grow to the greatest size for that variety. As one recedes

from a center the converse is true. The varieties, in some cases species, become fewer and those most rigidly dependant upon definite conditions are eliminated. In even the more tolerant varieties, the individuals begin to dwindle in size. Finally, as with the native plants the centers of dispersal and the centers of distribution are not necessarily the same, so in the crop plants the places where the greatest yields per acre are secured and the regions of greatest production may be widely separated. Indeed, in the case of wheat this is actually true.

The fundamental difference in the occurrence of plants belonging to the natural vegetation and the crop plants lies in cultivation. Man intervenes in behalf of the crop plant which must succeed in spite of the unnatural conditions which it faces. This perfectly obvious truth is repeated here because of the far-reaching effects of plant culture in determining the distribution of the crops when beyond their natural centers. As will be shown, this distribution is quite contrary to the distribution of the natural vegetation.

The indigenous plants beyond their centers can be found in the poorest habitats only where the struggle for existence is equally keen for the invaders from another center and for the members of the center. In Ohio, the white pine from the northern evergreen center and the scrub pine, *Pinus virginiana,* from the southern evergreen center meet on the rock cliffs east of the glacial boundary. Neither one of these invaders can compete with the deciduous forest species that make up the culminating associations in the better habitats. Another example of invaders joining one another in poor habitats is the unique association of the cactus, *Opuntia rafinesquii,* from the southwest and the Jack pine, *Pinus banksiana,* from Canada. The two are found together on the sand dunes near Chicago.

When the crop plants, on the other hand, are to be taken beyond their respective centers they must be given the richest land of the farms. In New York and eastern Pennsylvania when it is desired to grow corn the best fields are employed and these have to be further reinforced and amended by the use of manures. In the Connecticut River valley where tobacco is grown is seen a still more striking instance of man's interposition. Not only are the soil conditions altered but in order to obtain profitable yields the climatic conditions must be altered also by growing the plants under canvas. This shades the plants, lowering the transpiration rate during the day, while at night it prevents too great a loss of heat by radiation. The

climate thus artificially synthesized is more like that which obtains in the center of tobacco production.

The forest centers are plastic groups of plant associations which increase or decrease in size, migrating with climatic changes and movements of the earth's crust. The crop centers are also motile and even less stable than the forest centers. In addition to the physiographic and other physical factors which cause the forest centers to migrate there are economic developments and shiftings in the centers of population which may cause the crop centers to move. The problem becomes still further complicated in the case of the crops grown primarily for human food. Wheat is an example of this. Production is frequently attempted in regions to which the plants are not suited. In time these crops tend to become grouped about their respective centers. The process of change, however, may be a long, slow, and extravagant one.

One often hears that the great cereal crops are moving westward. This is nothing more than the gradual grouping of the centers of production of these crops in the area included between the 40-percent and 100-percent rainfall-evaporation ratio lines. This is where the crops can best be grown. When the United States was first settled by the white man he grew the grain he wanted in regions where it can not be profitably grown now because of competition with other parts of the country where grain production is cheaper than it is along the Atlantic Coast. If the census data from 1849 to date are examined a steady westward migration of the center of wheat production will be plainly seen. It has taken considerably more than half a century to move the center of wheat production about 100 miles north and about 700 miles west or, in other words, from the northeastern evergreen center to the prairie-plains center. When the climatic limits for all varieties of wheat have been reached the western advance, already slowed down, will halt because of limited moisture. It is as yet too early to predict the effect in pulling the wheat center westward of the intermountain edaphic plains regions.

Two economic factors which aided the movement of the wheat center northwest where it is now are, first, the invention in 1870 of a milling device known as the purifier. By its use a handsomer though not a more nutritious flour could be made from spring wheat. Hard spring wheat at once jumped from the least desirable class of wheat for flour to the most desirable class. The movement of wheat towards its center already well begun by the Civil War took a definite step northwest as the result of this invention. The second

factor is the coming of the railroads into the "World's Breadbasket."

But the processes of movement have been too haphazard, uncertain. Unencouraged by the Federal Government and without direction from the experiment stations the movement of crops toward their centers goes on too slowly. In the reorganizations sure to occur within the next few years it is greatly to be desired that the extravagant practices connected with trying to coax a crop from plants not growing in the proper habitats be given attention. Crop ecology, a not yet developed point of view, will have to be made the basis of more intensive studies in crop adaptation and improvement if we are to cope more successfully with the food-supply problems of the coming generations. Seemingly very few of the investigators of crops problems are aware of the importance of the ecological researches that have already been and are being carried on. Many of these have a direct bearing on crops.

As soon as we know more about the possibilities of producing a given crop in any region the difficulties of marketing to the greatest advantage of both the producer and the consumer will be in a position to be solved. Labor and transportation adjustments can be made when the amount of work to be done and the amount of material to be transported can be estimated.

The Centers of Crop Production.

We are now in a position to examine the geography of the crop centers to discover the relation that they bear to the climatic and edaphic factors of the regions in which they are to be found. Because of the limited space it has been necessary to pick out a few crops only from the many plants cultivated in the United States. It will be noticed in those selected that the choice has been on an economic basis purely, and not because these plants showed remarkably close agreement with any particular conceptions or theories. It would be difficult to substitute readily something else in the place of all the crops given. They therefore have distinct economic value. If, then, there is correlation with the known vegetation centers, it is not because of a prejudice or through skillfully selecting a few plants that would be sure to fit. The selection with respect to the biotic centers has been haphazard. We would be safe in supposing that other crops would show agreement at least as close as those presented.

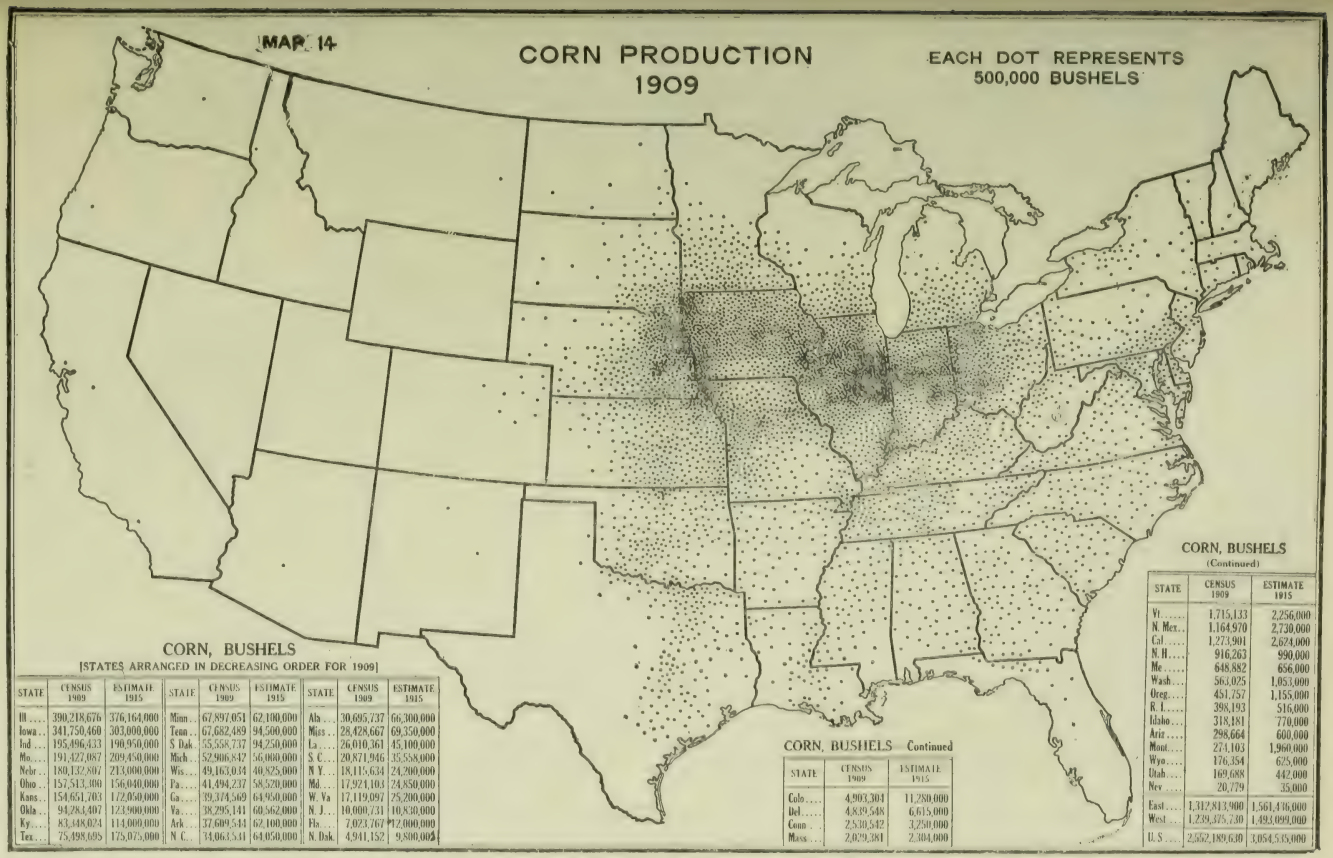
A. THE ATLANTIC COAST TO THE GREAT PLAINS.

The corn and wheat belts agree with the deciduous forest and the prairie centers in the United States. Production of these crops is greatest between the 60-percent evaporation line on the west and the 100-percent and 110-percent lines on the east (see fig. 5).

Three sets of factors are operating in combination to establish this region as the center for the production of our great cereals. These factors may be grouped as climatic, edaphic, and economic. While it is impossible to separate and distinguish these groups of forces in their actual operation, as canceling any one of them would not only destroy the end result but would seriously disturb the equilibrium of the other two, yet there is a strong temptation to analyze the relative weight of these sets of factors.

Without adding any more to the already lengthy discussions of the origin of maize, it is enough to say that it probably had its beginnings in the tropics or the subtropics, showed early a remarkable mutability and adaptability under cultivation so that within perhaps 2,000 years after cultivation began it reached a wide variety of forms and attained a wide geographic distribution. By reason of the hot, almost tropical summers with the relative humidity rather high and the annual rainfall sufficient for the growth of the plant, the entire area from Ohio to central Nebraska on the north and southward to the Gulf of Mexico is suited to corn production. Why, then, when the map (fig. 7) is examined do we find the greatest amount of production in the northern tier of States? This distribution seems odd and could only have been arrived at after a good deal of trouble in finding varieties which could grow under conditions so far from the original environment of the plant. The seven adjacent States from Ohio to Nebraska constitute our "corn belt" and produce 58 percent of the total quantity grown in the United States. Another question which the map provokes is why eastern Illinois is the region of greatest production within the center.

Neither of these questions can be answered simply and directly. On the other hand, to go into all the causes and effects would carry this paper far beyond its original scope, namely, to show where the centers of crop production are located and to suggest as briefly as possible a few of the more obvious reasons which brought them where they are. The climatic factor in Indiana and Ohio is suited to the profitable production of corn, but production centers in Illinois for edaphic reasons. The soil in the eastern portion of this



CORN, BUSHELS
[STATES ARRANGED IN DECREASING ORDER FOR 1909]

STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915
Ill....	390,218,676	376,164,000	Minn...	67,897,051	62,100,000	Ala...	30,695,737	66,300,000
Iowa...	341,750,460	303,800,000	Tenn...	67,682,489	94,500,000	Miss...	28,428,667	69,350,000
Ind....	195,496,433	190,950,000	S. Dak.	55,558,737	94,250,000	La....	26,010,361	45,100,000
Mo....	191,427,087	209,450,000	Mich...	52,906,842	56,000,000	S. C...	20,871,946	35,558,000
Nebr...	180,137,807	213,000,000	Wis....	49,163,034	40,825,000	N. Y...	18,115,634	24,200,000
Ohio...	157,513,300	156,040,000	Pa....	41,494,237	58,520,000	Md...	17,921,103	24,850,000
Kans...	154,651,703	172,050,000	Ga....	39,374,569	64,950,000	W. Va	17,119,097	25,200,000
Okla...	94,284,407	123,900,000	Va....	38,295,141	60,562,000	N. J...	10,000,731	10,830,000
Ky....	83,448,024	114,000,000	Ark...	37,609,544	62,100,000	Fla....	7,023,767	12,000,000
Tex....	75,498,695	175,075,000	N. C...	34,063,541	64,050,000	N. Dak.	4,941,152	9,800,000

CORN, BUSHELS Continued

STATE	CENSUS 1909	ESTIMATE 1915
Colo....	4,803,304	11,280,000
Del.....	4,839,548	6,615,000
Conn...	2,510,542	3,250,000
Mass...	2,029,581	2,304,000

CORN, BUSHELS
(Continued)

STATE	CENSUS 1909	ESTIMATE 1915
Vt.....	1,715,133	2,256,000
N. Mex..	1,164,970	2,730,000
Cal....	1,273,901	2,674,000
N. H....	916,263	990,000
Me.....	648,882	656,000
Wash...	563,025	1,053,000
Oreg....	451,757	1,155,000
R. I....	398,193	516,000
Idaho...	318,181	770,000
Ariz....	298,664	600,000
Mont....	274,103	1,960,000
Wyo....	176,354	625,000
Utah...	169,688	442,000
Nev....	20,779	35,000
East...	1,317,813,900	1,561,436,000
West...	1,239,375,730	1,493,099,000
U. S....	2,552,189,630	3,054,535,000

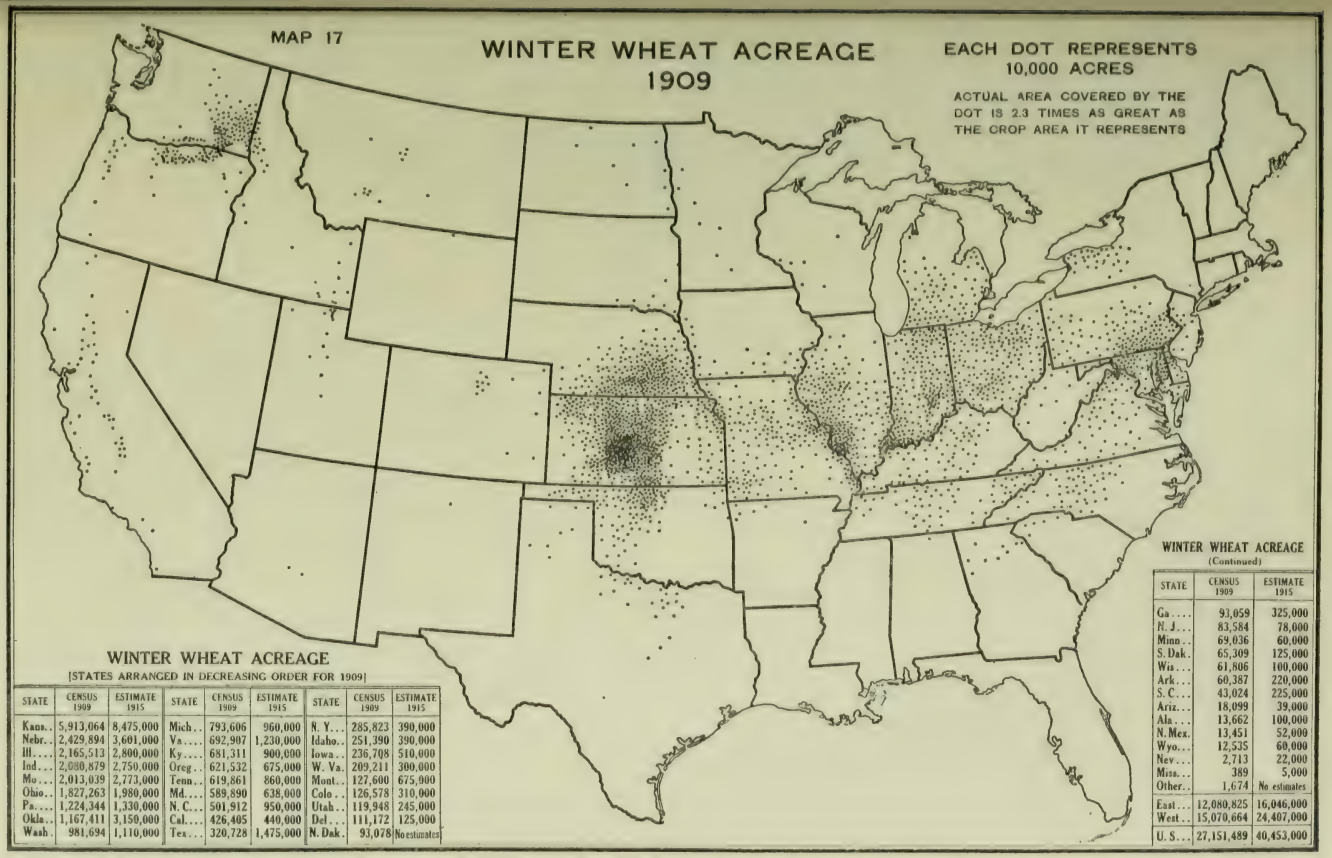
Fig. 7. Map of the United States showing corn production. Most of the level land suited for cultivation lying between the 60 percent and the 100 percent evaporation lines can and should be more intensively farmed for greater corn production. This chart and fig. 5 should be compared. From 1915 Yearbook of the U. S. Dept. of Agriculture. Compiled from unpublished census figures.

State is deeper and richer in humus that can be found elsewhere. Farther southward, where competition with the cotton crop begins, economic reasons prevent a center of corn production from developing. The occurrence of cotton south of Kentucky is a competing factor for both land and labor.

In the United States the average annual yield per acre of wheat for the period 1903–1912 is 14.1 bushels. During that same decade England's acre yield seems to have been 32 bushels, Germany's 30.1, France's 21, and Russia's but 9.7. There is an almost exact inverse proportion between production and yield per acre that offers a fascinating puzzle, for, of the countries named above, Russia and the United States are the greatest wheat producers of the nations. France, Germany, and England follow, not in immediate, consecutive positions but in the order named.

Wheat has come into universal interest and finds its way into every country of the world, which is for it an open market, because it has the capability of adapting itself readily to cultivation under widely different conditions. In the United States wheat production centers on the 60-percent rainfall-evaporation ratio line as can be seen by comparing figures 8 and 9 with figure 5. This means that the center of wheat production lies west of the best corn lands, although on many farms throughout the prairie and deciduous forest climaxes both wheat and corn are usually grown if rotations are practiced. In the matter of growing wheat in regions too dry for corn the United States is not an exception to the rule. The great wheat-producing regions all over the world are level plains with a cool, rather dry climate. It is known that wheat, particularly winter wheat, yields larger crops in the more humid sections, yet in normal times other crops can be grown in the humid parts of the United States with greater profit than wheat. It is competition with these crops that drives wheat to the plains.

A direct effect of climate can be seen in the quality of wheat. Wheat grown in the cooler, drier climates is, in general, harder and darker in color than that grown in the moister, warmer parts of the country. The relative amounts of gluten and starch in the endosperm, determined by the length of the favorable ripening season, are climatic responses. East and south of the 80-percent evaporation line wheat is soft and starchy, with large grains of red, amber, or white color. From the 80-percent limits on the east, westward to where there would be an 80-percent evaporation line extended if there were no prairie peninsula, the wheat is semihard. On and


MAP 17
WINTER WHEAT ACREAGE
1909
EACH DOT REPRESENTS
10,000 ACRES
ACTUAL AREA COVERED BY THE DOT IS 2.3 TIMES AS GREAT AS THE CROP AREA IT REPRESENTS

WINTER WHEAT ACREAGE

[STATES ARRANGED IN DECREASING ORDER FOR 1909]

STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915
Kans..	5,913,064	8,475,000	Mich..	793,606	960,000	N. Y....	285,823	390,000
Nebr..	2,429,894	3,601,000	Va....	692,907	1,230,000	Idaho..	251,390	390,000
Ill....	2,165,513	2,800,000	Ky....	681,311	900,000	Iowa..	236,708	510,000
Ind....	2,080,879	2,750,000	Oreg..	621,532	675,000	W. Va.	209,211	300,000
Mo....	2,013,039	2,773,000	Tenn..	619,861	860,000	Mont..	127,600	675,900
Ohio..	1,827,263	1,980,000	Md....	589,890	638,000	Colo..	126,578	310,000
Pa....	1,224,344	1,330,000	N. C...	501,912	950,000	Utah..	119,948	245,000
Okla..	1,167,411	3,150,000	Cal....	426,405	440,000	Del....	111,172	125,000
Wash..	981,694	1,110,000	Tex....	320,728	1,475,000	N. Dak..	93,078	No estimates

WINTER WHEAT ACREAGE

(Continued)

STATE	CENSUS 1909	ESTIMATE 1915
Ga....	93,059	325,000
N. J....	83,584	78,000
Minn..	69,036	60,000
S. Dak.	65,309	125,000
Wis....	61,806	100,000
Ark....	60,387	220,000
S. C....	43,024	225,000
Ariz....	18,099	39,000
Ala....	13,662	100,000
N. Mex.	13,451	52,000
Wyo....	12,535	60,000
Nev....	2,713	22,000
Miss....	389	5,000
Other..	1,674	No estimates
East....	12,080,825	16,046,000
West....	15,070,664	24,407,000
U. S....	27,151,489	40,453,000

FIG. 8. Map of the United States showing winter wheat acreage. From 1915 Yearbook of the U. S. Dept. of Agriculture. Compiled from unpublished census figures.

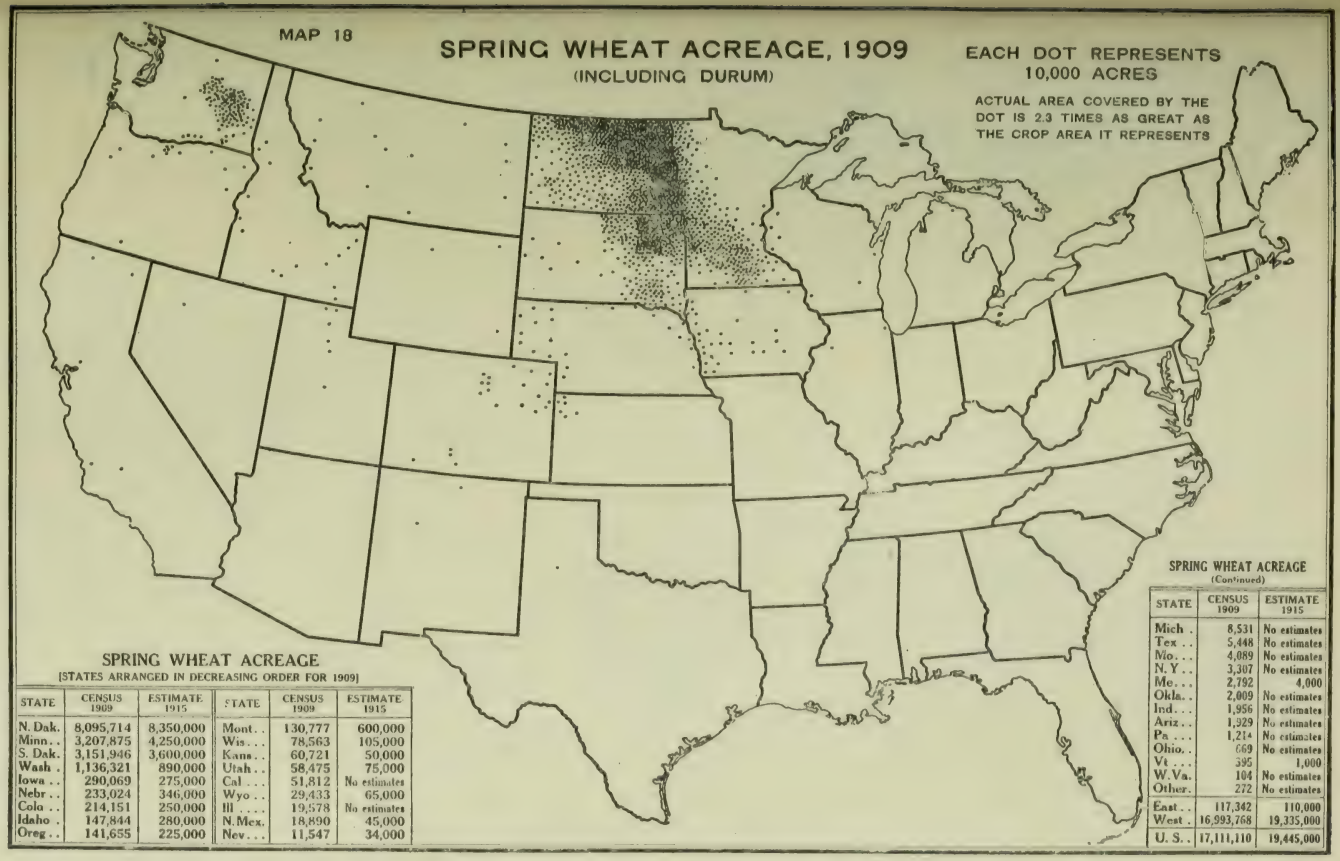
near the 60-percent evaporation line the wheat is darker in color and harder. It makes a flour that is known as "strong." This means that as its gluten percentage is higher, the volume of the loaf is greater than from an equal amount of yeast and flour made from a "weaker" or starchier kind of wheat.

An inspection of the spring wheat chart (fig. 9) shows production to center on the northern extension of the 60-percent line where all the evaporation lines are rather close together and nearly parallel. Ecologically, spring wheat could as well be grouped with the crops of the northeastern center, but geographically it belongs with the prairie climax. Edaphic considerations, then, rather than climatic, locate the area of spring wheat production. In Michigan and in Wisconsin the climate is as well suited to producing spring wheat as is the climate of those States farther west where production centers. Where spring wheat and barley are grown we find a great level tract of rich soil, a bequest of the old glacial Lake Agassiz. If wheat were a native plant indigenous to this climatic section of the United States, it would be found here a larger plant and in a greater variety of forms than in Michigan, where we may imagine its occurrence also. As however, it is a cultivated crop, the migration of which is controlled by man, we can see one valid explanation from among many others why its occurrence is limited in the way the chart shows. It is again a matter of profits.

While the eastward distribution is cut off sharply because of edaphic conditions, we can see in the climate only a vague and rather general determiner of the distribution north and south. This can be interpreted as meaning that physiological races have by no means approached the limits of their adaptability and convertability. Spring wheat, mostly durum, is found in both Nebraska and Kansas.

Oats center slightly north of the corn belt. Climatically, the center of production would be expected much farther northward. Edaphic reasons, and the convenience of a spring-sown crop rather than a fall-sown one to follow corn in the rotation now largely in practice in the corn belt push the center somewhat to the south.

This southward advance can only be accomplished by the introduction of small, early maturing varieties which are able to make most efficient use of the available moisture. The commonly cultivated oats supposed to have arisen from the *Avena fatua* group of wild oats succeed in cool moist climates similar to that of their origin. While the origin of some of the early-maturing varieties is at present unknown, there is reason to believe that one at least, Burt,



SPRING WHEAT ACREAGE
[STATES ARRANGED IN DECREASING ORDER FOR 1909]

STATE	CENSUS 1909	ESTIMATE 1915	STATE	CENSUS 1909	ESTIMATE 1915
N. Dak.	8,095,714	8,350,000	Mont. .	130,777	600,000
Minn. .	3,207,875	4,250,000	Wis. . .	78,563	105,000
S. Dak.	3,151,946	3,600,000	Kans. .	60,721	50,000
Wash .	1,136,321	890,000	Utah . .	58,475	75,000
Iowa . .	290,069	275,000	Cal . . .	51,812	No estimates
Nebr . .	233,024	346,000	Wyo . .	29,433	65,000
Colo . .	214,151	250,000	Ill	19,578	No estimates
Idaho .	147,844	280,000	N. Mex.	18,890	45,000
Oreg . .	141,655	225,000	Nev. . .	11,547	34,000

SPRING WHEAT ACREAGE
(Continued)

STATE	CENSUS 1909	ESTIMATE 1915
Mich .	8,531	No estimates
Tex . .	5,448	No estimates
Mo. . .	4,089	No estimates
N. Y. .	3,307	No estimates
Me. . .	2,792	4,000
Okla. .	2,009	No estimates
Ind. . .	1,956	No estimates
Ariz. .	1,329	No estimates
Pa . . .	1,214	No estimates
Ohio. .	669	No estimates
Vt . . .	595	1,000
W. Va.	104	No estimates
Other.	272	No estimates
East . .	117,342	110,000
West .	16,993,768	19,335,000
U. S. .	17,111,110	19,445,000

FIG. 9. Map of the United States showing spring wheat acreage. Note the distribution is cut off sharply east and west, while north and south there is no marked line where production ceases. See text for discussion. From 1915 Yearbook of the U. S. Dept. of Agriculture.

may have come from *Avena barbata*. This is a group that offers opportunity for valuable genetic and systematic study.

The region south and east of the 100-percent rainfall-evaporation ratio line is ecologically known as the southeastern evergreen center. While the rainfall throughout this part of the country is greater than it is northward, higher temperatures cause much more rapid evaporation. The physiological water requirement is higher.

Cotton is the principal crop plant of this region. Eastward the extension of the southern Appalachians makes too rough a topography for the production of a cultivated crop. Temperature is the limiting factor of production northward; moisture is the limiting factor westward beyond central Texas. For present purposes the southern boundaries of Kentucky and Virginia may be considered the limit of cotton production, although there is a slight acreage in both of these States (fig. 10).

There is not space to give in detail all the crops produced in this region or to dwell on their ecological significance. The study of the maps (figs. 5 and 10) shows beyond doubt that the cotton belt and the southeastern evergreen forest are two names for the same region. The same influences operating to make this country distinct biologically operate in the determination of the crops produced here. For other crop charts the reader is referred to the 1915 Yearbook of the United States Department of Agriculture, from which the maps reproduced here were obtained. It is suggested that the same principles of grouping the maps employed here be followed when the other crop charts are examined.

It is interesting to note that although cotton is a cash crop and can be converted into money more easily than most crops of the country, yet even with this advantage competition with other crops prevents cotton from reaching the limit of production. These crops are: Tobacco in North Carolina and Tennessee, sugar cane and rice in Louisiana, rice in Texas and sweet potatoes, cowpeas, and peanuts in most of the States included by the cotton belt.

The northeastern evergreen forest lies to the north and east of the 110-percent evaporation line. It is in area the most extensive of the centers, spreading southward down the Appalachians into Georgia and Alabama, westward through Ontario, northern Michigan, Wisconsin, and Minnesota, and continuing northwest to the Bering Strait, with a more northerly distribution than the western plant formations. (See fig. 5.)

From the point of view of farm crops this center is restricted to

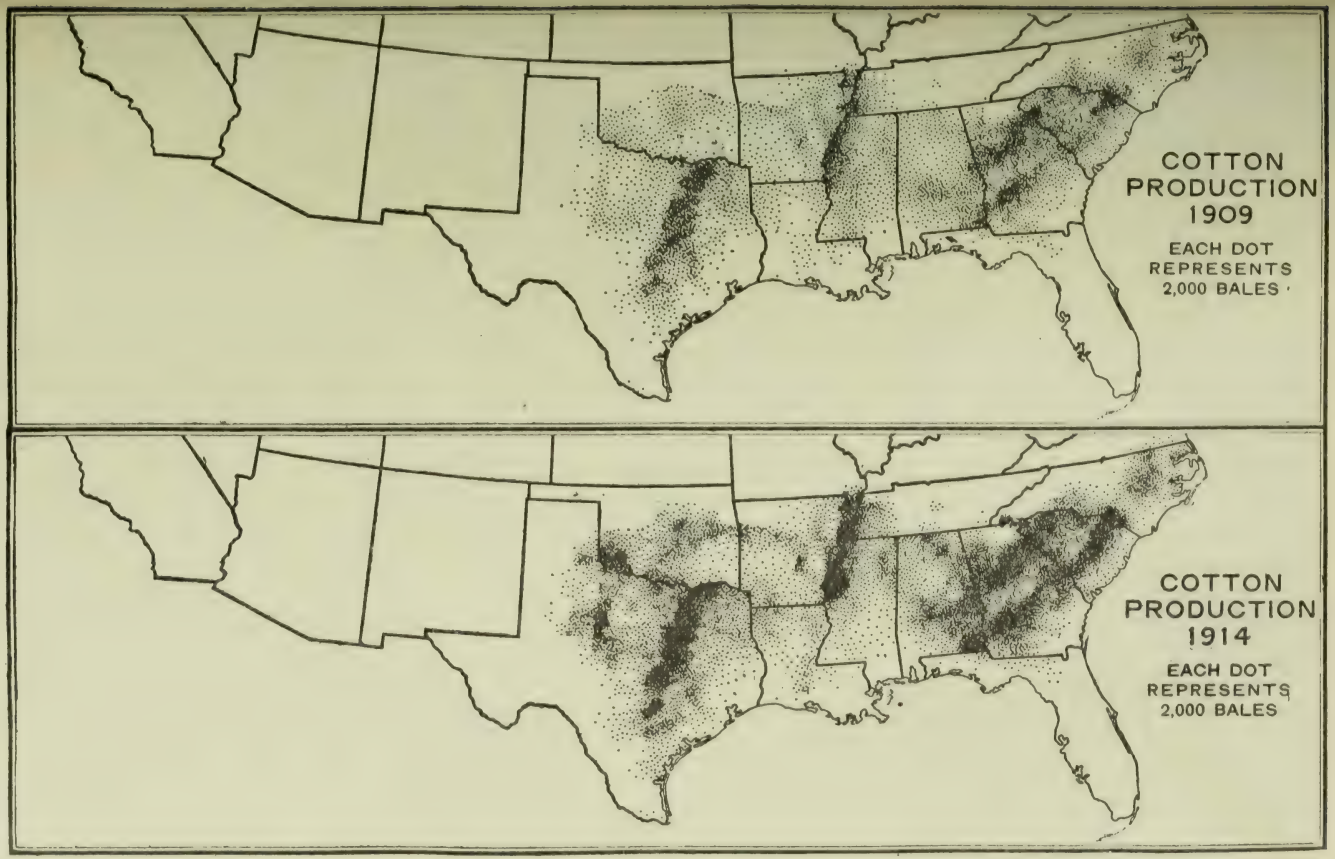


FIG. 10. Cotton production in 1909 and 1914 compared. Note the geographic relation of the cotton-belt States to the corn-belt States. Compare with figure 5. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

New England and New York, extending through certain sections of Pennsylvania. This is the tame hay and pasture region of the United States. When it is again noted how closely the prairie-plains climax and the northeastern evergreen climax approach one another in the Dakotas and Minnesota, the problem of placing spring wheat will be appreciated. The reasons for discussing this crop under the prairie-plains climax have already been given.

In New York and New England over 50 percent of the improved land is in hay or some forage crop (fig. 11), while if the pasture land is added to this it will be found that from 80 to 90 percent of the improved land is in pasture, hay and forage.

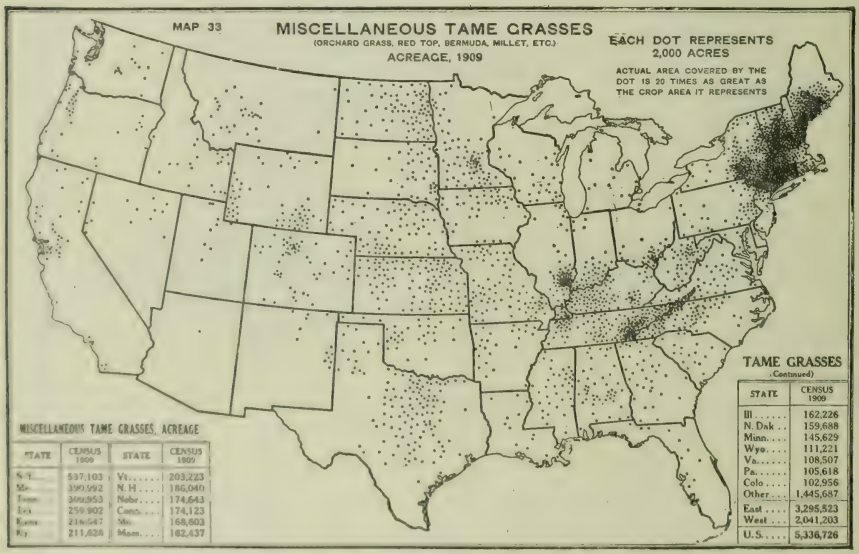

MAP 33
MISCELLANEOUS TAME GRASSES
(ORCHARD GRASS, RED TOP, BERMUDA, MILLET, ETC.)
ACREAGE, 1909
EACH DOT REPRESENTS 2,000 ACRES
ACTUAL AREA COVERED BY THE DOT IS 20 TIMES AS GREAT AS THE CROP AREA IT REPRESENTS
MISCELLANEOUS TAME GRASSES, ACREAGE
STATE | CENSUS 1909 | STATE | CENSUS 1909
S. T... 537,103 | Vt..... 203,223
Mo... 390,992 | N. H.... 186,040
Tenn... 366,953 | Nebr.... 174,643
Ind... 259,902 | Conn.... 174,123
Kans... 216,547 | Me. 168,803
Ky. 211,628 | Mass.... 162,437
TAME GRASSES
(Continued)
STATE | CENSUS 1909
Ill..... 162,226
N. Dak.. 159,688
Minn.... 145,629
Wyo.... 111,221
Va..... 108,507
Pa..... 105,618
Colo.... 102,956
Other... 1,445,687
East.... 3,295,523
West... 2,041,203
U.S.... 5,336,726

FIG. 11. Acreage of miscellaneous tame grasses. These include orchard grass, redtop, Bermuda, millets, and others. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

The climatic reason for the great and increasing production of fodder in this region is that the lower temperatures make cereal production less profitable than in the respective centers of these crops. This brings out clearly the rather strange fact that although both wheat and oats are climatically adapted for this center, maize is the premier cereal of America and seems to serve as a foundation upon which the production of the other cereals is built. Edaphically the thin, stiff soils of this center and the uneven topography limit the production of crops that must be cultivated. Timothy is

the leading hay crop. Timothy and red clover are grown together for mixed hay, but clover alone is not so important in this center as it is in the alluvial soils of the lower Ohio and Wabash basins.

Rye is an important grain crop of the northeastern center and in time of want could be made an appreciable source of breadstuff. Since rye bread is already known favorably to many people the fancied hardship of having bread that is not snow white could probably be overcome with rye flour sooner than with some other kind of wheat substitute. In Germany and Russia rye and wheat have been used interchangeably for years. Buckwheat also is important in this region and if demand came for it, production could be increased. It should be noted that buckwheat is the only crop cultivated for its edible grain that remained centering in the east during the time that the cereals have been carried westward.

The center of white potato production, while of course being dispersed in the neighborhoods of towns and cities for economic reasons that seem to take on more weight than the fundamental climatic and edaphic considerations, appears nevertheless to establish a fairly close relation with the northeastern evergreen center. This means that of the crops now used for that purpose the potato is the principal one for human food that is produced in this center. Potatoes seem, more than most plants, dependent upon soil conditions. Extensive investigations are now in progress to discover the varieties best suited to particular edaphic situations. Besides New England, another center of potato production is seen in the intermountain basin in Colorado wherever the natural moisture or irrigation makes its growth possible.

B. THE PLAINS.

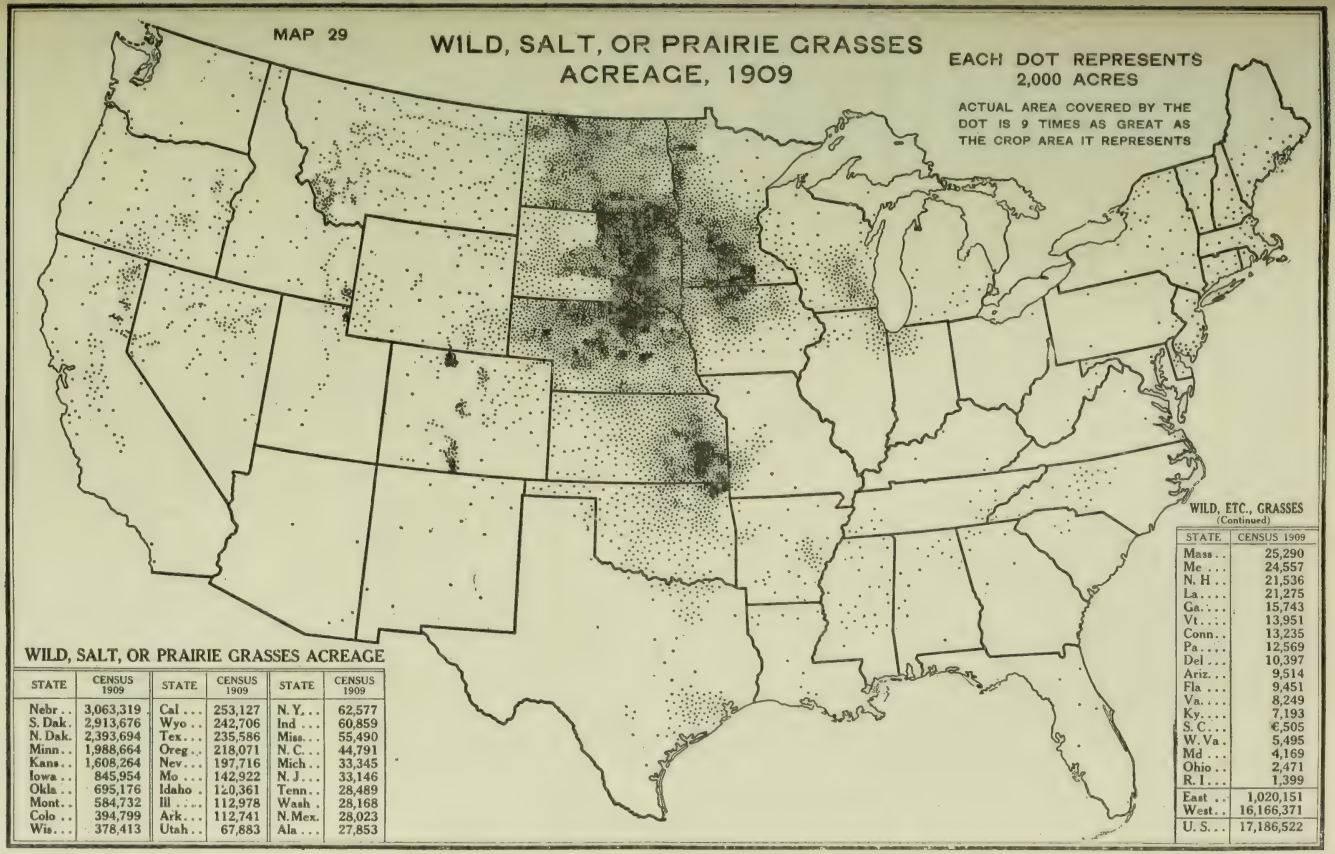
Turning now to the western half of the United States we find that throughout by far the greatest portion of this area evaporation consistently exceeds precipitation two or more times. In order to live under such drought conditions plants must conserve water in an extreme degree. The effect of the limited moisture in determining the plant forms which best succeed in the face of this aridity is illustrated by contrasting the barrel cactus and the elm. The former is almost spherical and compacted into the least possible evaporating surface, the latter with its deliquescing trunk melts into many branches and leaves spread to the lightest breeze. The cultivated plants of the plains climax must be grown under the best known methods for saving and utilizing all the water that can be captured by the soil and under irrigation.

Climatically the plains mark a step toward greater drought than the prairies, just in the same way that the prairies are more arid than the forests. The plains lie west of the 60-percent rainfall-evaporation line, extending to the 20-percent line. The latter follows in general the north and south trend of the mountains at their eastern base (fig. 5). The severe continental climate that prevails is characterized by the high winds, sudden changes in temperature, and the unequal and slight distribution of the precipitation both summer and winter. It is this unequal distribution that renders ineffective much of the moisture that is precipitated. In the southwestern part of the plains where temperature and evaporation are greatest there is a gradual and imperceptible merging into desert conditions.

The direction of the prevailing winds is not such as to bring the moisture (in the form of an evaporation-reducing blanket of air, rather than actual precipitation) from the Gulf of Mexico, the Atlantic, and the forest of eastern America near the Plains. This might be stated in another way by saying that after the moisture from the east reaches the prairies it is dissipated into the higher air currents caused by the absorption and radiation of heat by the great land mass of North America. The discussion of "climatic origins" has already indicated this feature of continental climates.

Kansas is divided by the 60-percent evaporation line, so the agriculture of the east and west section of this State may be examined for the effects of moisture. In the east there is still sufficient moisture for the production of corn and the other crops commonly grown under the general methods of farming of the eastern United States. West of the line there is not sufficient moisture for this sort of farming and a quarter of a century ago the land had no agricultural value except for grazing. It has been pointed out that in Illinois is an edaphic plains area that is in agricultural essentials similar to the climatic plains region.

A revaluation of the land and a reorganization of agricultural practice was effected by the introduction into western Kansas of such efficient users of water as alfalfa, milo, and kafir. Land which was regarded 25 years ago as nearly useless cannot be bought under $50 an acre now. The system of farming that must be practiced in these lands of little water precludes the possibilities of a crop of even the water-conserving plants every year. The land is sometimes fallowed and allowed to accumulate moisture for a full crop every second year, as this has been found a more profitable method than growing a partial crop each year.



WILD, SALT, OR PRAIRIE GRASSES ACREAGE

STATE	CENSUS 1909	STATE	CENSUS 1909	STATE	CENSUS 1909
Nebr..	3,063,319	Cal...	253,127	N. Y...	62,577
S. Dak.	2,913,676	Wyo..	242,706	Ind...	60,859
N. Dak.	2,393,694	Tex...	235,586	Miss...	55,490
Minn..	1,988,664	Oreg..	218,071	N. C...	44,791
Kans..	1,608,264	Nev...	197,716	Mich..	33,345
Iowa..	845,954	Mo...	142,922	N. J...	33,146
Okla..	695,176	Idaho.	120,361	Tenn..	28,489
Mont..	584,732	Ill....	112,978	Wash.	28,168
Colo..	394,799	Ark...	112,741	N.Mex.	28,023
Wis...	378,413	Utah..	67,883	Ala...	27,853

WILD, ETC., GRASSES (Continued)

STATE	CENSUS 1909
Mass..	25,290
Me...	24,557
N. H..	21,536
La....	21,275
Ga....	15,743
Vt....	13,951
Conn..	13,235
Pa....	12,569
Del...	10,397
Ariz..	9,514
Fla...	9,451
Va....	8,249
Ky....	7,193
S. C...	6,505
W. Va.	5,495
Md...	4,169
Ohio..	2,471
R. I...	1,399
East..	1,020,151
West..	16,166,371
U. S...	17,186,522

FIG. 12. Grasslands from which the natural vegetation can be used as hay or pasture. Note the proximity to the 60 percent evaporation line. From the 1915 Yearbook of the U. S. Dept. of Agriculture.

In western Kansas the soil is permanently dry below a depth of 5 or 6 feet. In eastern Colorado a depth of 2 feet or perhaps less would bring one to the same condition. This comparison not only emphasizes the change toward greater aridity but indicates also the differences in possible crop production. It must be borne in mind that in all of these divisions of the United States there are many factors in operation which modify locally the influence of the climate. The data from agricultural experiment stations will continue for a number of years to be so meager that it will indicate crop possibilities in only the barest outline. It is safe to predict that production is likely to increase in this part of the country. The introduction of new plants suited to the conditions is going on at a surprising rate. Methods of studying the environment are improving and cooperation between the workers in different fields of endeavor is becoming greater.

Grazing and pasturing and the production of forage are the principal agricultural activities of the Plains climax. The wild hay and native pasture grasses must still be given the leading position in crop rank (fig. 12). Among the planted crops, alfalfa is easily first. The chart of alfalfa production shows its importance near the 60-percent evaporation line. Farther west, centers of production can be regarded as irrigated localities, or as regions where the intermountain rain and snow make its existence possible. South of the principal alfalfa center, but still near the 60-percent evaporation line, coarse forage is extensively produced. This part of the southwest plains has not reached the semidesert conditions of New Mexico and Arizona.

Charts of plains crops, i. e., alfalfa, plains wild grasses, and such coarse forage as milo and kafir, indicate subdivisions of a region where the gross physiognomy of the vegetation is largely the same. The divisions of the plains are ecologically related to the prairie and the forest centers in a way that corresponds to the relations brought out by the plant geographers studying the prairie-plains vegetation.

C. THE PACIFIC COAST.

The third distinct climatic division of the United States is the narrow strip of territory from the Pacific Coast to the mountains. It may be rather roughly divided into a northern and a southern half. The northern half is the region of greatest rainfall in the United States, more than a hundred inches being recorded as the annual average. Under the heading of the Pacific Coast the intermountain basins east of that region may be mentioned because of

their geographic relations with this area. It should be understood that in these basins there are great variations in both moisture and temperature conditions. In general, it may be said that evaporation increases from north to south. This brings out the fact that these intermountain basins have their climatic counterparts in one of the three general climatic divisions. When more complete evaporation studies have been made, data will be at hand by which the exact climatic nature of each of these localities can be determined.

The proximity to a large water reservoir and the direction of the mountain chains and of the prevailing winds are the features which express themselves in the abundant rainfall of the Pacific Coast. In the northern part where the rainfall is greatest and evaporation least a super-forest develops. Douglas fir and one of the cedars form this giant forest. Weaver (1914) has traced the development of the vegetation in eastern Washington and Idaho and finds that the subclimax is composed of Pseudotsuga and Larix, often with *Abies grandis*. The real climax consists of the cedar, *Thuja plicata,* consociation. On the lower levels a scrub forest, or as it is more familiarly known, the chaparral, predominates. We are safe in believing that in the scrub forests evaporation begins to exceed rainfall and the moisture obtainable from the melting snows. In the extreme south and not a great distance from the coast is the desert.

The topography limits the distribution of the sequoias, which are to be found only near the mouths of the canons where there is exposure to the foggy atmosphere, protection from excessive evaporation, and the possibility of obtaining water circulating underground within reach of their roots. Topography also determines largely the evaporation and so controls the vegetation of the intermountain valleys. Some places are semideserts, even approaching desert conditions, e. g., the Snake River. Others present edaphic plains, prairie, or forest climaxes.

The northern part of the Pacific Coast is primarily a hay-prdoucing region just as is New England. There is a notable feature peculiar to this region due to the abundant rainfall. It is the customary practice to use for hay plants the same crops which in the Middle West are grown mainly for their grain. Wheat and barley are used as forage crops and are classed by the census enumerators as "grains cut green." It is also possible that some day the center of the bulb-growing industry for the United States may be located in favorable situations in this part of the country. The apple industries of the moister river valleys of Washington, Oregon, and Idaho are famous

all over the world. In a number of localities in this region enough wheat is grown to make an important wheat center.

In the southern part of the Pacific Coast region annual crops are largely replaced by tree crops, walnuts, citrus fruits, olives, and other perennials.

Animal Centers.

This account would not be complete without some reference, however slight, to the animal industries that follow the production of plants. The reader is urged to examine the charts on livestock in the 1915 Yearbook of the United States Department of Agriculture and compare them with the rainfall-evaporation ratio chart and the crop centers.

Adams (1915) has shown that the insect communities of a forest and a prairie are totally different. This indicates the same adjustment to physiological requirements that has been seen in the plants. It also indicates something of the dependence of animals upon certain plants for their food. The interrelations between plants and animals growing out of this fundamental dependence are enormous. Adams's report will have to be read in full to appreciate something of it. Back of the interrelations between plants and animals is the relation of both to the physical factors of their environment.

The presence of certain wild plant species in a locality is sufficient to account for the occurrence of insect species (Adams, 1914, loc. cit., p. 46). It is a more widely known fact that the introduction of wheat into America was shortly followed by the introduction of the Hessian fly. This insect has spread everywhere by following the path of its favorite food plant. It is almost a foregone conclusion that a map showing the limits of wheat distribution would also show the limits of the distribution of the Hessian fly. The Colorado potato beetle was able to spread to all parts of the United States because paths had been made for it by planting potatoes and one of these happened to touch a natural center for the beetle. Such instances as these could easily be multiplied.

We might perhaps be inclined to believe that the adjustments of animals to plant development could most easily be found among the insects, a numerous and highly specialized group. But the responses are universal and are to be seen whether we go up or down the evolutionary scale. Adams reports prairie and forest spiders and snails, while Hankinson (1915) distinguishes the forest vertebrates, ranging from fish to mammals, from the prairie vertebrates, ranging from

amphibians and reptiles to mammals. The work of Thompson-Seton (1909) on the North American mammals should also be consulted in this connection. Many charts of both herbivorous and carnivorous animals, together with many notes on their distribution, are presented in the two volumes of his work. These maps show that the biological centers may be examined from many angles, depending upon the particular field of endeavor of the worker, but that, after all, the centers are expressions of the same interactions of climatic and edaphic factors. The distribution of the striped ground squirrel, *Citellus tridecemlineatus,* marks the prairies. Its range carries it across Illinois eastward into Indiana and Ohio, and it is also seen in the sand plain of southern Michigan. In the plains, the prong-buck, *Antilocapra americana,* has its food habits fixed by its environment. In captivity attempts to give it other food than the familiar grass, cactus, and sagebrush have proven unsuccessful.

Much more readily observable is the dependence of the domesticated animals upon the cultivated plants. Reference to the charts in the 1915 Yearbook will show that the dairy industries are located in the northeastern evergreen center and on the Pacific Coast. These regions it will be remembered are the natural tame hay and pasture centers of the United States. Economic reasons also enter into this, of course, but the significance of a cool moist climate with an abundant production of forage reasonably certain every year is too large a fundamental fact to overlook. Beef cattle and swine are found centering in and slightly west of the corn belt. Their relations to the great grain-growing areas are not difficult to perceive. The greatest production of horses is in the region just north of the corn belt. This is the present center of oats production also. Mules are supposedly sturdier work animals than horses. They are found centering in the cotton belt because, more in the past than at present, grain and fodder was not produced in the cotton belt and so good feed was difficult to get. Also, as their drivers were less likely to be careful of work stock, there was a greater chance of survival after ill treatment.

Sheep are abundant in the arid regions. Though production is greatest in the West, there is also an important center in Ohio and Pennsylvania. On the whole this distribution is most interesting and brings out several important facts. First it should be noted that the sheep of the East and Middle West are more likely to be mutton sheep and the wool produced is only a byproduct. Unfortunately

there is no way of determining easily just how far this is true. The distribution in the West must be regarded as climatic, since sheep can find a living from vegetation on which other animals would perish, and the western distribution shows sheep to be limited to the rather sparsely vegetated areas. Further, not only does climate determine the distribution of sheep, but it also controls the method of handling them. Because there is not enough vegetation to feed them in any one place, they must be driven to follow the growth of vegetation which springs up after the rainy seasons. This is especially true in Wyoming and Montana, the two greatest wool-producing States, and in the drier portions of Oregon and southern California.

The center in Ohio and Pennsylvania is significantly located east of the glacial boundary, where the rougher topography favors pasturing. In addition to pasture, access to grain and fodder is not difficult and the feeding of the sheep in winter is a part of the method of handling. The eastern Ohio and western Pennsylvania center of sheep raising is essentially an edaphic center.

Many of the statements in the foregoing paper can not be appreciated fully until the relation of the crop centers to the centers of the natural vegetation has been completely analyzed. The intensive methods used by the ecologists in the study of the habitat, namely, the use of instruments for the exact observation of the moisture and temperature and photographs to record plant growth in relation to the surroundings, can not be too strongly emphasized. In a number of instances the measurements found by ecologists who have used standardized vaporimeters are applicable to agricultural studies. In all studies of evaporation, edaphic factors sometimes operating with and sometimes against the climatic, deserve the most careful interpretation. These in turn are dependent upon the present and historic geology and topography.

Summary.

The crop centers of the United States agree with the biotic centers. In detail this means that the corn and winter wheat belts correspond to the deciduous central forest and the prairie climaxes, the tame hay and pasture region to the northeastern evergreen forest, the cotton belt to the southeastern evergreen forest, and so on. The rainfall-evaporation ratio map is useful for the demarcation of these centers because in it are included four factors of climate, namely, relative humidity, temperature of the evaporating surface, and wind velocity

as the divisor, and precipitation as the dividend. These four factors are of profound importance to plant growth.

Edaphic factors frequently determine the distribution of the cultivated plants. Edaphic and climatic factors, although they may be independent of one another in their operation, sometimes cause the same agricultural practices to be employed. Economic factors modify the influence of climate and soils.

A fundamental difference between crop plants and the natural vegetation is seen when plants are found beyond their usual centers. The crops are found on the best soils only, since that is their sole chance to compete with other crops for profit. Plant invaders of the indigenous vegetation migrating from their centers can offer competition in the poorest habitats only. In the better habitats the plants belonging to the center are little influenced by invaders.

In addition to the exotic crops being given the best fields, further soil modifications are usually introduced. In the extreme cases, climatic as well as soil modifications are practiced. Field plants are then grown on a comparatively large scale under glass or cloth shelter.

The domesticated animals are grouped about the centers of production of those crops upon which they are most dependent.

The methods used in studying plant succession have been used here. It is in this field of research that an accurate interpretation of conditions as consequences of the operation of physical forces of the past and present has been made. Migration, including invasion and competition, the latter implying dominance, are the direct results of interaction of climate and soils upon vegetation.

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CHANGES IN THE NITROGEN CONTENT OF STORED SOILS.[1]

WM. A. ALDRECHT.

Certain determinations for soil nitrogen at the Missouri Agricultural Experiment Station have shown marked evidence of increases having taken place during storage. As the soil samples in question had been stored in containers which were not airtight and as some of the samples were moist, the possibility of bacterial fixation at first suggested itself. As the room where the samples had been stored adjoined the laboratory in which more or less ammonia was being used it seemed more probable that the increase was due to direct ammonia adsorption.

Literature on the adsorption of gases by soils puts ammonia as one of the gases most easily adsorbed. Schlösing found that a moist soil exposed to the air adsorbed nitrogen at the rate of 38 pounds per acre per annum, which was mainly in the form of ammonia. This adsorption took place whether the soils were acid or alkaline, dry or wet (7).[2] A. D. Hall, of Rothamsted (1), after studying ammonia absorption from the air by means of sulfuric acid, states that "the maximum absorption per annum amounts to less than a pound per acre." In testing the amounts of ammonia that soils will adsorb from an unlimited supply, Muntz and Gerard found that 1 kilogram of garden soil took up 5.38 grams of ammonia (4). The

[1] Contribution from the Department of Soils, University of Missouri. Received for publication September 4, 1917.

[2] Figures in parentheses refer to papers similarly numbered in "Literature cited," page 88.

presence of various substances in the soil increases the adsorptive capacity for ammonia. It has been shown that calcium carbonate (7), ferric hydroxide, and organic matter (2) have marked effects, while moisture is not as effective as one would suppose (6).

Lyon, Fippin, and Buckman (3) state that—

> Absorption of gases by soils is largely an adsorption phenomenon, the gases being condensed on the surface of the particles. The absorption is greater, the finer the particles of soil, but this increase is not directly proportional to the increase in surface, large particles apparently having a greater absorptive power than their surface would indicate.

As a surface phenomenon the amount adsorbed will be dependent on such factors as partial pressure, temperature, viscosity of the vapor, physical condition, chemical composition, and others. When the gases are once adsorbed, they are maintained with marked tenacity, as is shown by glass, which holds hygroscopic moisture at temperatures as high as 500° C. Sufficient evidence is available to emphasize the fact that the soil is a powerful adsorber of gases. This mass of information suggested the possibility of contamination of stored samples through this means. The following study was undertaken to find out whether contamination by adsorbed ammonia or bacterial activity was responsible for variation of the nitrogen in stored samples.

The plan of storage and treatment of the soil was as follows. Two soils widely different in nitrogen content were collected; one a Shelby silt loam with 2,325 pounds, and the other a Summit clay loam with 7,950 pounds of nitrogen in 2,000,000 pounds of surface soil. Each sample was thoroughly mixed and divided into three parts. On one part the determinations of nitrate, ammonia, and total nitrogen were made as soon as possible after collecting. The second part was put into a room adjoining the general soils laboratory and spread out on a table. Determinations of the three forms of nitrogen were made four weeks later. The third portion of the soil was put into bags in the moist condition and stored in a basement room to dry slowly for analysis two months later.

The analytical methods were those commonly used. Nitrates were determined by extracting the over-dried soil with $\frac{N}{10}$ hydrochloric acid, making it alkaline, boiling off the ammonia, reducing with Devarda's metal, and distilling. The ammonia was measured by distilling the soil and magnesium oxide with compressed air and steam, while the total nitrogen determination was according to the

official method modified for nitrates by use of sodium thiosulfate. The samples were thoroughly mixed each time and sieved through an 80-mesh sieve for total nitrogen determinations and through a 20-mesh sieve in the other cases. All determinations were calculated on a water-free basis. Each sample for total nitrogen was dried in an oven at 107° C. for eight hours and then transferred to a flask for digestion. Calculations of pounds per acre were based on each separate water-free sample. For receiving nitrate and ammonia distillations, a $\frac{N}{28}$ sulfuric acid was used and duplicates checked within 0.2 c.c. for the nitrates but not so closely for ammonia. For total nitrogen analysis a $\frac{N}{14}$ acid was used, and determinations again checked to 0.2 c.c. All samples except in a few cases were run in quadruplicate.

Table 1 gives the data from the different nitrogen determinations. The figures are averages calculated from four determinations.

TABLE 1.—*Variation in amounts of ammonia, nitrate, and total nitrogen of a soil stored under different conditions.*

AMMONIA NITROGEN.

Date of determination and place stored.	Silt soil.		Clay soil.	
	Weight of water-free soil.	Nitrogen.	Weight of water-free soil.	Nitrogen.
	gms.	*mgs.*	*gms.*	*mgs.*
On day sampled	82.60	1.53[a](1.48–1.58)	71.55	1.50(1.30–1.73)
Dried 28 days near laboratory	83.28	2.31(2.14–2.50)	80.37	2.66(2.57–2.72)
Dried 56 days in basement	82.70	1.45(1.32–1.60)	78.95	1.58(1.47–1.73)

NITRATE NITROGEN.

On day sampled	61.97	Trace	53.66	Trace
Dried 28 days near laboratory	63.68	Trace	61.45	0.310(.255–.357)
Dried 56 days in basement	63.24	Trace	60.37	0.340(.255–.408)

TOTAL NITROGEN.

On day sampled	9.79	10.96(10.69–11.12)	9.480	37.64(37.45–37.84)
Dried 28 days near laboratory	9.80	11.32(11.19–11.49)	[b]9.46	39.32(39.19–39.48)
Dried 56 days in basement	9.73	11.21(11.09–11.38)	9.29	37.77(37.58–37.92)

[a] Figures in parentheses denote limits of variations in figures from which averages were calculated. Variations in hygroscopic moisture determination were less than 6 milligrams for the 10 gram samples.

[b] Three determinations only.

The total nitrogen on the day sampled in the silt soil was 2,237 pounds per acre in 2,000,000 pounds of surface soil, variations 2,183 to 2,263 pounds; in the clay soil, 7,943 pounds (7,901–7,981). In the soils dried 28 days in the laboratory, the total nitrogen was, silt soil, 2,311 pounds (2,284–2,345), and clay soil, 8,315 pounds (8,286–8,350). In the soils dried 56 days in the basement, the total nitrogen was, silt soil, 2,306 pounds (2,280–2,339), and clay soil, 8,133 pounds (8,097–8,164).

The data given for the ammonia nitrogen in Table 1 indicate an increase in this form when the soil was dried near the laboratory, while there was no increase when stored in the basement room. This indicates contamination by gaseous ammonia rather than bacterial action, for if the latter agent had been responsible the sample stored in the basement should have given an increase in ammonia also. Bacteria seemed to be playing no rôle in a measurable way.

The nitrates remained largely unaffected by storage, even though the clay loam shows less nitrogen as nitrate on the day of sampling than when stored. No explanation for this is offered.

The total nitrogen showed an increase with storage, particularly when the soil was kept near the laboratory. With silt soil this increase was small, but with the clay loam quite significant, though the determinations are a trifle erratic in the latter case. The data as a whole indicate that there is no significant change in the nitrogen by bacteria.

The above results prompted another series of analyses on the silt soil only, to test the possibility of contamination of both moist and dry soils by ammonia. Several portions of a large sample of soil were treated as follows. One part was analyzed for ammonia and total nitrogen as soon after sampling as possible. A second portion was dried in the laboratory where ammonia was used. The third part was dried in a greenhouse located in an orchard away from any ammonia. As soon as the soil in the greenhouse was well dried, analyses were made on some of it, and the remainder was divided into halves, leaving one half in the greenhouse and transferring the other half in the laboratory where it was spread out near an evaporating dish containing about 60 c.c. of ammonium hydroxide. This procedure was followed since no ammonia was being used in the room at that time. The data are given in Table 2. Determinations were made in sets of four and figures given are averages.

TABLE 2.—*Ammonia and total nitrogen in silt soil as affected by different conditions of storage.*

Time of sampling and place stored.	Ammonia nitrogen.		Total nitrogen.		
	Water-free soil.	Nitrogen in sample.	Water-free soil.	Nitrogen in sample.	Nitrogen in 2,000,000 pounds of surface soil.
	Grams.	*Mgs.*	*Grams.*	*Mgs.*	*Pounds.*
Fresh soil	79.73	1.01 [a](0.86–1.12)	9.6609	11.248 (11.189–11.288)	[b] 2,328 (2,317–2,335)
Dried in greenhouse 10 days	77.85	1.23 (1.07–1.37)	9.7320	11.275 (11.189–11.388)	2,316 (2,298–2,340)
Dried in laboratory 10 days	77.91	2.91 (2.75–3.11)	9.7382	11.474 (11.437–11.537)	2,356 (2,348–2,370)
Dried and stored in greenhouse	78.13	1.72 (1.65–1.78)	9.7662	11.409 (11.371–11.468)	[c] 2,337 (2,328–2,347)
Dried in greenhouse and stored in laboratory near ammonia	78.30	60.43 (60.04–60.81)	9.7878	19.041 (18.823–19.114)	3,890 (3,846–3,906)
Dried in greenhouse and stored near ammonia; samples not heated			[d] 9.7878	18.823 (18.678–18.969)	[c] 3,846 (3,816–3,876)

[a] Numbers in parentheses denote range in variations. Hygroscopic moisture determinations varied no more than 6 milligrams in a 10-gram sample.

[b] Three determinations only.

[c] Two determinations only.

[d] Water-free soil figured from sample above.

The data in Table 2 show beyond a doubt that both the moist and dry soils have taken up nitrogen as ammonia when stored in a laboratory in which ammonia fumes are present in considerable amounts. The sample dried in the greenhouse and then exposed in a dry state to ammonia fumes adsorbed enough to give 1,553 pounds per acre increase in the total nitrogen. In the distillable ammonia there was an increase by drying in the laboratory and an unusual increase for the dry soil left near an ammonia container. The increase in ammonia nitrogen over the sample when first collected amounts to 1,517 pounds per acre, corresponding closely to the increase of 1,553 pounds per acre of total nitrogen. Evidently the use of small amounts of ammonia in the laboratory is sufficient to increase markedly the nitrogen in a soil exposed there. That the ammonia is not held by the moisture present in the soil is indicated by the increase of nitrogen

when the dry soil was brought from the greenhouse and stored near the ammonia. This soil had but 2.75 percent of moisture, yet took up the equivalent of 1,517 pounds of nitrogen per acre. Ammonia thus taken up is held strongly enough so that heating for eight hours at 107–108° C. does not drive it off. This is shown by the figures for those samples analyzed without first heating them in an oven as compared with those heated. That the nitrogen is taken up in the form of ammonia is shown by the fact that the increase of this element is distillable with magnesium oxide. In the form of ammonia, the nitrogen is held, not by moisture, but by adsorption as a purely physical phenomenon.

This brief study indicates that in case of soils stored in or near a laboratory in other than air-tight containers, there is a grave danger of contamination by ammonia, whether the soil is wet or dry. It indicates further that when moist soils are left to dry slowly there is little danger of bacterial action measurably affecting the nitrogen content.

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NAMING WHEAT VARIETIES.[1]

CARLETON R. BALL AND J. ALLEN CLARK.

Crop varieties must be distinguished by names. These names must be used frequently by a host of agronomic workers as well as by crop growers and crop users. The form and appropriateness of these names, therefore, are of general interest. It is desirable that they be short, simple, and appropriate, easily spelled and pronounced. It also is desirable that a single name of this kind be designated and accepted for each recognized variety.

CONFUSION IN VARIETAL NAMES.

The multiplication of names and other designations for crop varieties has been carried to great extremes. The resulting confusion also is very great, especially in those crops like wheat where the number of actual varieties is very large. These names and near names may be classified into three series, as follows: (1) Names, (2) descriptive phrases, and (3) numbers. As examples of names, Fulcaster, Fultz, Jones Fife, and Kubanka may be cited. As examples of descriptive phrases we may quote Bluestem, Early Red Clawson, Jones Paris Prize, Purple Straw, and White Australian. Numbers applied in place of names may be typified by Iowa No. 404, Minnesota No. 163, and Washington Hybrid No. 128.

At the present time, the existing confusion and multiplication of varieties places a great burden on agronomic workers. It renders uncertain and difficult the interpretation of published results of experiments. This confusion occurs in two principal ways. (1) The same name is applied to very different varieties in different parts of the country; (2) The same variety passes under several different names in different parts of the country, or even in the same part.

Good examples of the same name, or rather descriptive phrase, applied to different varieties are Bluestem and Red Russian. In the Far West, Bluestem is an awnless variety with glabrous white glumes and white soft kernels, usually spring-sown. According to Leighty, an eastern fall-sown variety with similar spike and kernel characters

[1] Contribution from the United States Department of Agriculture, Washington, D. C. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 14, 1917.

is known as Kentucky Bluestem. In the upper Mississippi Valley, Bluestem is a spring-sown awnless wheat with pubescent white glumes and red hard kernels. In the eastern United States, the names Alabama Bluestem and Georgia Bluestem are applied to fall-sown awnless wheats with glabrous white glumes and red, midsized, soft kernels, while Pennsylvania Bluestem differs in having brown glumes.

The descriptive phrase-name, Red Russian, is applied to four and perhaps five different varieties in this country. In the humid districts of the Pacific Northwest it is applied to a fall-sown variety with large, clavate, awnless spikes, glabrous white glumes, and red large soft kernels. In the Great Plains area and westward, the name Red Russian is commonly applied to the Russian winter wheats of the Crimean group, as Crimean, Kharkov, and Turkey. These have small fusiform awned spikes, white glabrous glumes, and red midsized hard kernels. In the northern part of the Great Plains area, the name Red Russian is applied to a spring-sown variety, similar in general appearance to the Crimean winter wheats, but differing in spring habit, glume characters, and semihard kernels. A fourth variety called Red Russian is grouped by Leighty with those eastern wheats having awnless spikes with glabrous brown glumes and red soft kernels. The list of names which have been applied to at least two different varieties is too long to present here.

The second case mentioned was where the same variety passes under two or more varietal names. Here the real difficulty is to prove that the varieties bearing different names are really identical. This is a much more difficult task than determining strikingly evident differences, and is completed only after careful study and comparison. Here too we must recognize that there are differences of performance not necessarily correlated with visible characters. For such cases the necessary allowance must be made.

There remain, however, many cases in which the identity of varieties bearing two or more different names is evident. The Crimean group of hard red winter wheats, the dominant crop in Kansas, Nebraska, and Oklahoma, is a good illustration. Alberta Red, Crimean, Kharkov, Malakov, Red Russian, Torgova, and Turkey are only different names for a single variety. It may be called Crimean, or Kharkov, or Turkey with equal accuracy. Beloglina, on the other hand, can be separated from these others on one minor character, namely, the longer beaks and squarer, more deeply notched shoulders of the glumes. Kanred, a pure line separated from

Crimean, C. I. No. 1437, was bred and named by the Kansas Agricultural Experiment Station. It is, however, a true Beloglina, and differs from other Beloglinas only in consistently higher yield, so far as known.

Another good illustration is the Pacific Bluestem, the dominant spring variety of the Columbia and Snake River basins in the Pacific Northwest. Research has shown it to be identical with the White Australian, which has been the dominant variety of California for fully 60 years.

In addition to the different kinds of confusion of names which have been discussed, there are many examples of objectionable names of other sorts. Many varietal designations are long and cumbersome descriptive phrases; for example, Early Red Clawson, Jones Silver Sheaf Longberry, etc. Others are equally long and cumbersome numbers, as, for example, Minnesota No. 169, Nebraska Hybrid No. 28, or Washington Hybrid No. 143. Another disadvantage in using numbers as names is that an error in a single numeral renders the variety unrecognizable.

The facts and conditions set forth in the preceding discussion can be amplified almost without limit. They seem to the writers to show the need for some concerted action on the part of agronomic workers. The writers are about to begin the publication of a classification of wheats. In it varietal names must be used and confusion in their use avoided. This means that duplication of the same varietal name for different varieties can not be recognized. Conversely, different names for the same variety must be eliminated.

A Proposed Code of Nomenclature.

A brief but comprehensive code of nomenclature is presented herewith for the consideration of the members of the American Society of Agronomy. It is hoped that it may be adopted in some form at this meeting, so that the authors may have opportunity to select varietal names for their classification in accordance with its rules. In this way, whatever names are used would have the backing of a responsible body of agronomists.

Code of Nomenclature.

The following rules governing the naming of varieties of crop plants are hereby proposed for consideration and adoption by the American Society of Agronomy, at the annual business meeting on November 13, 1917.

1. Eligibility to Naming. No variety shall be named unless (*a*) distinctly different from existing varieties in one or more recognizable characters, or (*b*) distinctly superior to them in some character or quality, and unless (*c*) it is to be placed in commercial culture

2. Priority. No two varieties of the same crop plant shall bear the same name. The name first published (see Rule 4) for a variety shall be the accepted and recognized name, except in cases where it has been applied in violation of this code.

A. The term, "crop plant," as used herein, shall be understood to mean those general classes of crops which are grouped together in common usage without regard to their exact botanical relationship, as corn, wheat, sorghum, cotton, potato, etc.

B. The paramount right of the originator, discoverer, or introducer of a new variety to name it, within the limitations of this code, shall be recognized.

C. Where the same varietal name has become thoroughly established for two or more varieties, through long usage in agronomic literature, it should not be displaced or radically modified for either one, except where a well-known synonym can be substituted. Otherwise the varieties bearing the same name should be distinguished by adding some suitable term which will insure their identity.

D. Existing American varietal names which conflict with earlier published foreign names for the same or different varieties, but which have been thoroughly established through long usage, shall not be displaced unless long-used and available synonyms exist.

3. Form of Names. The name of a variety shall consist of a single word.

A. Varietal names shall be short, simple, distinctive, and easily spelled and pronounced.

B. A varietal name derived from a personal or geographical name should be spelled and pronounced in accordance with the rules governing in the case of the original name.

C. The name borne by an imported foreign variety should be retained, subject only to such modification as is necessary to conform it to this code.

D. The name of a person should not be used as a varietal name during his lifetime. The name of a deceased person should not be so used except by the official action of this or other competent agronomic bodies. Personal names in the possessive form are inadmissible.

E. Names of stations, States, or countries, in either the nounal or adjectival form should not be used as varietal names.

F. Such general terms as hybrid, selection, pure-line, pedigreed, seedling, etc., should not be used as varietal names.

G. A number, either alone or attached to a word, should not be used as a varietal name, but considered as a temporary designation while the variety is undergoing preliminary testing.

H. Names which palpably exaggerate the merits of a variety shall be inadmissible.

I. In applying the provisions of this rule to varietal names which have become firmly established in agronomic literature through long usage, no change shall be made which will involve loss of identity.

4. Publication. A varietal name is established by publication. Publication consists (1) in the distribution of a printed description of the variety named, giving its distinguishing characters, or (2) in the publication of a new name for a variety properly described elsewhere, such publication to be made in any book, bulletin, circular, report, trade catalog, or periodical, provided the same bears the date of issue and is distributed generally among agronomists and crop growers; or (3) in certain cases the general recognition of a name for a commercial variety in a community for a number of years may be held to constitute publication.

A. Where two or more admissible names are given to the same variety, in the same publication, that which stands first shall have precedence.

5. Citation. In the full and formal citation of a varietal name, the name of the author who first published it shall be given.

6. Revision. No properly published varietal name shall be changed for any reason except conflict with this code, nor shall another variety be substituted for that originally described thereunder.

Explanatory Comments on the Rules.

The first clause (*a*) of Rule 1 will prevent the recognition of several different names for the same variety. Clause *b* permits the naming of pure-line selections, hybrids, etc., which have superior merit, even though not distinguishable by external characters.

Rule 2 will govern the use of such names as Bluestem, Red Russian, etc., when applied to two or more different varieties. Paragraph C provides against confusion which would result from completely discarding well-known names.

Rule 3 governs the formation of acceptable names. Canadian and Australian wheat breeders have set a splendid example in the application of short, simple, and appropriate names to the varieties they originate. Names like Huron, Marquis, Prelude, Preston, Pioneer, and Stanley in Canada, or Bobs, Comeback, Federation, Firbank, and Warren in Australia leave nothing to be desired. The various explanatory paragraphs, A to I, inclusive, show how the rule is to be applied in special cases. The ultimate effect will be to do away with long, cumbersome, and oftentimes misleading descriptive phrases and selection numbers now used as names. Paragraph I prevents confusion through the complete loss of familiar names of long standing.

Rule 4 provides for the proper publication of varietal names. Williams[2] has given an admirable example of this in publishing his

[2] Williams, C. G. Wheat experiments. Ohio Agr. Expt. Sta. Bul. 298: 465–466. May, 1916.

three new varieties, Gladden, Portage, and Trumbull. Fuller descriptions will be desirable in official publication of new varieties.

Rule 5 is of little consequence and can be eliminated without serious loss. It merely gives some credit to the author of a varietal name when discussing a variety in any formal or important connection, such as description or classification, or in an alphabetical checklist of all known varieties. Some of the varieties mentioned above would then appear as follows: Marquis (Saunders); Bobs (Farrer); Monad and Buford (Ball & Clark);[3] Portage (Williams), etc.

Rule 6 governs changes of varietal names.

Copies of this proposed code have been sent to Prof. E. G. Montgomery, *chairman*, Prof. C. G. Williams, and Dr. H. K. Hayes, comprising the committee on varietal nomenclature of this Society. It is hoped that their discussion of it may be presented here before final action is taken.[4]

AGRONOMIC AFFAIRS.

ANNUAL DUES FOR 1918.

Those who have not already paid their dues for 1918 are urged to send checks promptly to the Secretary-Treasurer, P. V. Cardon, U. S. Department of Agriculture, Washington, D. C. Prompt remittance saves the Secretary-Treasurer much correspondence and insures continuous delivery of the JOURNAL. Under the by-laws of the Society, the JOURNAL is not to be sent after April 1 to those whose dues are not paid before that time. The sending of back numbers entails extra work on the officers and adds materially to the Society's expense account. If your dues are not already paid, remit now and get each number as it appears. Don't forget that the amount is $2.50. And be sure to notify the Secretary of any change of address.

[3] Ball, Carleton R., and Clark, J. Allen. Experiments with durum wheat. U. S. Dept. Agr., Bul. 618: 44, 46. 1918.

[4] The code, as here proposed, was adopted in its entirety, together with some additions proposed by the committee. It is published in the report of the committee (JOUR. AMER. SOC. AGRON., 9: 425-427. December, 1917).

THE SOCIETY'S HONOR ROLL.

For some time, the Editor has planned to begin the publication of an honor roll of those members of the American Society of Agronomy who are serving their country in the world war. Following is the list of those who are known to the Editor to be in the military forces of the United States or of Canada. No doubt there are many more. If you know of some member of the Society in the army or navy or engaged in war work whose name is not on the roll here printed, inform the Editor and the addition will be made.

Roll of Honor.

H. R. Cates,
A. D. Ellison,
Samuel D. Gray,
P. H. Kime,
E. E. Graham,
Leroy Moomaw,
J. V. Quigley,
Geo. T. Ratliffe,
L. C. Raymond,
F. J. Schneiderhan,
W. R. Schoonover,
Herschel Scott,
Paul Tabor.

MEMBERSHIP CHANGES.

The membership reported in the January issue was 653. Since that time 6 members have resigned and 9 new members have been added, a net increase of 3 and a total membership of 656. The names and addresses of the new members, names of the members resigned, and such changes of address as have come to the notice of the Secretary-Treasurer are reported below.

New Members.

Earl Burtis, 325 East Olive St., Fort Collins, Colo.
Bruce J. Firkins, Dept. of Soils, I. S. C., Ames. Iowa.
Alex. Granowsky, 320 Plum St., Fort Collins, Colo.
Jerome Igo, 228 W. Magnolia St., Fort Collins, Colo.
Fred Maier, 400 S. Howes St., Fort Collins, Colo.
Sterling Minor, 318 W. Magnolia St., Fort Collins, Colo.
Glenn Paxton, Box 269, Fort Collins, Colo.
Nelson S. Smith, School of Agr., Olds, Alberta, Canada.
R. E. Stephenson, Dept. of Soils, I. S. C., Ames, Iowa.

Members Resigned.

Cobb, J. Stanley,
Garland, J. J.,
Jenson, Chas. A.,
Potter, R. S.,
Wood, M. W.,
Zerban, F. W.

CHANGES OF ADDRESSES.

ABELL, M. F., College of Agriculture, Storrs, Conn.
CURTIS, H. P., County Agent, Sutton, W. Va.
DUNNEWALD, T. J., 210 N. Carrol St., Madison, Wis.
GODDARD, L. H., 1324 Monroe St., Washington, D. C.
LUCKETT, J. D., States Relations Service, U. S. Dept. Agr., Wash.
MARIS, EDWIN I., Demonstration Agent, Atwood, Kans.
WARBURTON, C. W., 320 Flour Exchange, Minneapolis, Minn.

NOTES AND NEWS.

George F. Corson, formerly professor of agriculture at the Iowa State Teachers' College, has been appointed assistant in soil survey at the Iowa station.

H. B. Derr, for the past several years county agent in Scott Co., Mo., is now county agent in Fairfax Co., Va., with headquarters at Fairfax.

R. A. Dutcher, formerly assistant professor of agricultural chemistry at the Oregon Agricultural College, and C. A. Morrow, formerly professor of chemistry at Nebraska Wesleyan University, are now assistant professors of biochemistry in the Minnesota college.

A. D. Ellison, for the past two years in charge of the cereal experiments on the U. S. Department of Agriculture's Arlington Farm near Washington, D. C., is now with the gas defense service of the U. S. Army.

J. N. Else has been appointed assistant in agronomy in the Pennsylvania college and station.

A. D. Faville, animal husbandman of the Wyoming station, has been elected director of the station, succeeding H. G. Knight.

R. L. Furry, a graduate of the Missouri College of Agriculture, is assistant plant breeder on the Ferguson Seed Farms, at Sherman, Texas.

S. C. Harmon is assistant agronomist at the Virginia station.

R. E. Holland, formerly county agent in Kimball Co., Nebr., has been made assistant emergency county agent leader and has been succeeded in Kimball County by Paul H. Stewart, instructor in agronomy in the Nebraska college last year.

H. G. Knight, for the past several years director of the Wyoming station and dean of the college of agriculture, has been elected to a similar position in the Oklahoma college and station.

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THE EFFECT OF CERTAIN FACTORS ON THE CARBON-DIOXIDE CONTENT OF SOIL AIR.[1]

J. A. BIZZELL AND T. L. LYON.

REVIEW OF LITERATURE.

It has been suggested[2] that some higher plants exert an influence on certain bacterial processes in the soil. Experiments indicate that some higher plants may, during the most active period of their growth, stimulate the formation of nitrates, while during the later periods of growth the same plants may exert a depressing effect. Since the conditions favoring the formation of carbon dioxide in soils are similar to those favoring nitrification, it is logical to suppose that the two processes would parallel each other.

Russell and Appleyard[3] have recently produced evidence to show that, so far as the effects of temperature, moisture, and apparently aeration are concerned, such a correlation probably exists. The presence of the growing plant, however, introduces so many far-reaching and disturbing factors as to make it difficult to institute such comparisons when based on the ordinary methods of analysis. In the first place, carbon dioxide is produced not only by simple oxidation but also by plants, while nitrates are absorbed by plants. Again, under

[1] Contribution from the Laboratory of Soil Technology, College of Agriculture, Cornell University, Ithaca, N. Y. Received for publication October 23, 1917.

[2] Lyon, T. L., and Bizzell, J. A. Some relations of certain higher plants to the formation of nitrates in soils. Cornell Univ. Agr. Expt. Sta. Memoir No. 1. 1913.

[3] Russell, E. J., and Appleyard, A. The influence of soil conditions on the decomposition of organic matter in the soil. *In* Jour. Agr. Sci., 8: 385–417. 1917.

soil conditions the carbon dioxide produced is distributed between the liquid and gaseous phases. As the relative amount contained in each case is dependent on the content of water, calcium carbonate, and dissolved salts, it becomes difficult to determine quantitatively the effect of any one factor on the amount of carbon dioxide produced. It has frequently been observed that carbon dioxide is excreted by the roots of plants and that this process is in some way closely connected with the period of greatest vegetative growth. That there may be more deep-seated effects is indicated by results obtained by the authors. Boussingault and Lewy, Pettenkofer, Foder, Moller, Ebermayer, and other early investigators observed that soil air contains more carbon dioxide than atmospheric air. This phenomenon was attributed generally to the oxidation of organic matter. The fluctuations in the carbon-dioxide content of the soil air were apparently governed by seasonal conditions. The effect of cropping appears to have been first studied by Wollny,[4] who placed calcareous sandy soil in metal cylinders and determined the carbon dioxide in the air once each week during the summer and part of the winter months. Comparing grass sod with bare soil, he found less carbon dioxide under sod during the summer months and more during the winter months. He attributes the effect of the crop to its effect on the moisture, temperature, and porosity of the soil.

Dehérain and de Moussy[5] called attention to the fact that carbon-dioxide formation in the bare soil is due almost wholly to bacteria. They found that sterile soil at ordinary temperatures produces little carbon dioxide but that at points much above 65° C. considerable oxidation occurs by purely chemical means. They obtained large quantities of carbon dioxide by spreading soil in very thin layers and concluded that aeration is one of the most important factors.

Molisch,[6] in studying root secretions, found an enzyme which has the power to oxidize the organic compounds of humus. Czapek,[7] working along similar lines, produced evidence to show that the plant-root excretion which gives the acid reaction is carbonic acid. Wollny[8]

[4] Wollny, E. Untersuchungen über den Einfluss der Pflanzendecke und der Beschattung auf dem Kohlensäuregehalt der Boden Luft. *In* Forsch. Geb. Agrik.-Physik., 3: 1–15. 1880.

[5] Dehérain, P. P., and de Moussy, E. Sur l'Oxydation de la Matiére Organique du Sol. *In* Ann. Agron., 22: 305–337. 1896.

[6] Molisch, H. Über Wurzelausschied und deren Einwirkung auf Organische Substanzen. *In* Sitzungs Akad. Wiss. Wien-Math. Nat., 96: 84–109. 1888.

[7] Czapek, F. Zur Lehre von der Wurzelausscheidungen. *In* Jahr. Wiss. Bot., 29: 324.

[8] Wollny, E. Die Zersetzung der Organischen Stoffe. 1897.

demonstrated that, in the absence of free oxygen, organic matter may reduce the oxides of manganese and iron and form carbon dioxide. He also states that certain organic substances may form carbon dioxide by simple decomposition. Kossowitsch[9] grew mustard in nutrient solution mixed with washed quartz. He dissolved the carbon dioxide produced by percolating nutrient solution through the containers. This was so regulated as to give 5 liters of percolate in 24 hours. A check container on which no plants were growing was included. The carbon dioxide in the planted mixture increased gradually up to the end of the experiment when the plant was in full bloom, while the check varied within narrow limits.

Stoklasa and Ernst[10] grew barley, wheat, rye, and oats in nutrient solutions and determined the amounts of carbon dioxide produced at different stages of growth. The younger the plants and more tender the roots, the greater the quantities of carbon dioxide produced per gram of dry matter. Considering the total amounts of carbon dioxide produced, however, they found the maximum with plants 70 to 80 days old. At 84 days there were somewhat smaller quantities than at 80 days. They determined the quantity of carbon dioxide given off as gas by soil during 200 days. As the soil was bare of vegetation the action was attributed to bacteria. They obtained something more than twice the quantity of carbon dioxide estimated to be produced by wheat during 100 days. In a later article,[11] they investigated the chemical nature of root secretions and found carbon dioxide to be the principal one.

Amberson[12] observed that the mucilaginous covering of the root hairs contains a saturated solution of carbon dioxide. Lau[13] determined the carbon-dioxide content of soil air by a modification of the Petterson-Palmquist apparatus. He found that plant-root respiration has a marked effect upon the amount of carbon dioxide. It increased with the growth of the plant, reaching a maximum at the blooming

[9] Kossowitsch, P. The quantitative determination of carbon dioxide produced by the roots of plants during the period of their development. *In* Jour. Expt. Agr. (Russia), 5: 482–493. 1904. Translation by J. Davidson.

[10] Stoklasa, J., and Ernst, A. Über den Ursprung die Menge und die Bedeutung des Kohlendioxyds im Boden. *In* Centbl. Bakt., II, Abt. 14, S. 723–736. 1905.

[11] Stoklasa, J., and Ernst, A. Beiträge zur Lösung der Frage der Chemischen Natur des Wurzelseketes. *In* Jahrb. Wiss. Bot., 46: 55–102. 1908.

[12] Amberson, J. H. Ein Beitrag zur Kentniss der Natur der Wurzelausscheidungen. *In* Jahrb. Wiss. Bot., 47: 41–56. 1909.

[13] Lau, E. Beiträge zur Kentniss der Zusammensetzung der im Ackerboden befindlichen Luft. Inaug. Diss. Rostock. 1906.

period. Potatoes and lupines gave larger amounts than other crops. This was attributed to the fact that potatoes and legumes have a higher rate of respiration. The carbon-dioxide content in cropped plats reached a maximum at the root zone, while in uncropped soil the content increased directly with depth of sampling.

Barakov[14] grew lupines, clover, barley, rye, wheat, peas, vetch, potatoes, and sugar beets in lysimeters. Several different types of soil were used. Samples of soil air were collected by attaching retorts which had been exhausted to the tubes at the bottom of the lysimeters. The carbon dioxide was then determined by absorption in standard barium hydroxide solution. The author found that the maximum carbon-dioxide content as a rule coincided with the period of blooming. Contrary to the opinions of others he considers that plants produce much greater quantities of carbon dioxide in soil than do bacteria. He compared two lysimeters on which clover was grown. Both were harvested on June 14, and immediately thereafter the carbon-dioxide content decreased rapidly. In one lysimeter the clover sod was plowed under and the carbon dioxide continued to decrease. In the other lysimeter the clover was allowed to grow and the carbon dioxide increased to a maximum at the second blooming. The greatest quantity of carbon dioxide produced by bacteria was 6.9 mgr. per liter, while the highest produced by plants was 27.3 mgr. per liter. Barakov quotes the work of Souprounenko as showing that lysimeters bare of vegetation produced less carbon dioxide than did those on which millet was grown.

Comparing the effect of soil type, Barakov found that the ability of a particular plant to produce carbon dioxide is greater the more fertile the soil, and concludes that the effect is due directly to the more active vegetative growth on the fertile soil. He found that although the respiration curve varies with different plants, the maximum carbon-dioxide production occurs at the time of maximum life activity of a plant.

Van Suchtelen[15] mixed 6 grams of calcium oxide with 6 kilograms of soil and found the carbon dioxide produced to be less in the limed soil. On the other hand, magnesium sulfate, ammonium sulfate, and superphosphate stimulated carbon-dioxide production. The exper-

[14] Barakov, P. The carbon dioxide content of soils during different stages of growth of plants. *In* Jour. Expt. Agron. (Russia), 11: 321–342. 1910. Translation by J. Davidson.

[15] Van Suchtelen, F. H. H. Über die Messung der Lebenstätigkeit der Azotobacter Bakterien im Boden durch die Kohlensäureproduktion. *In* Centb. Bakt., II, Abt. 28, S. 45–89. 1910.

iments were meager and no statement is made as to the time intervening between application of salts and determination of carbon dioxide.

Stoklasa,[16] in making a study of bacterial action in soil, concluded that the greatest production of carbon dioxide occurs in neutral or slightly alkaline soil abundantly supplied with air and readily assimilable plant nutrients.

Lemmerman and his associates[17] quote the work of earlier investigators as showing decreased production of carbon dioxide in soil to which calcium oxide and calcium carbonate were added. Lemmerman found that applications of 0.1 percent, 0.5 percent and 1 percent of quicklime decreased production of carbon dioxide for the first two weeks, while the 0.5 percent and 1 percent applications continued to have the same effect for eight weeks. They also used calcium carbonate in quantities chemically equivalent to the quantities of calcium oxide. They found quantities corresponding to 0.1 percent CaO to be stimulative while the larger quantities gave a decrease in carbon dioxide. They conclude that the decrease with the quicklime was due to direct absorption of the gas produced with formation of calcium carbonate. They call attention to what they consider the errors that arise in experiments of this kind (1) when carbon dioxide only is determined and methane ignored, (2) when calcium oxide absorbs the carbon dioxide formed, and (3) when calcium carbonate is applied to acid soil, causing evolution of the carbon dioxide from the carbonate added.

Leather[18] studied carbon-dioxide production in soil by determining the total carbon dioxide present in the form of a gas and in solution as $Ca(HCO_3)_2$. This was done by taking a small soil core 4 cm. by 8 cm., placing in a suitable container, and removing the gas by means of a vacuum. The author maintains that determinations of the gaseous phase only do not represent carbon-dioxide production. From data obtained on the solubility of carbon dioxide as $Ca(HCO_3)_2$ at different pressures, the author estimates that when the total carbon dioxide is less than 10 percent and the soil is not particularly dry it

[16] Stoklasa, J. Methoden zur Bestimmung der Atmungsintensität der Bakterien im Boden. *In* Zeit. Landw. Versuch. Oesterr., 14: 1243–1279. 1911.

[17] Lemmerman, O., Aso, K., Fischer, H., and Fresenius, L. Untersuchungen über die Zersetzung der Kohlenstoffverbindungen Verschiedene organischer Substanzen im Boden, Speziele unter dem Einfluss von Kalk. *In* Landw. Jahrb., 41: 217–256. 1911.

[18] Leather, J. W. Soil gases. Mem. Dept. Agr. India., Chem. Ser., 4: 85–132. 1915.

is nearly all in solution. The author found larger quantities of carbon dioxide in the neighborhood of roots of crops than in fallow land.

Russell and Appleyard[19] determined the carbon dioxide content of soil air in samples obtained by simple aspiration through a tube placed about 6 inches below the surface. They found considerable fluctuation in the quantities of carbon dioxide. The variations were attributed principally to seasonal changes. From November to May the temperature and carbon dioxide curves almost coincide, but early in May they diverge and do not come together again until November. Plotting the rainfall for the week preceding date of sampling, a rather close relationship was brought out. The cropped plots showed higher

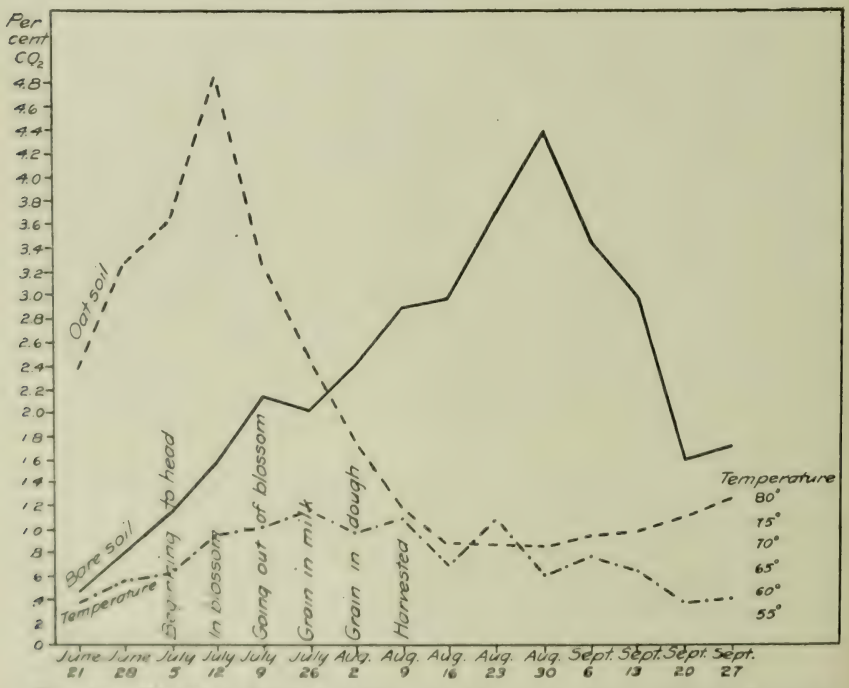

FIG. 13. Diagram showing carbon dioxide in air from unlimed Dunkirk clay loam, cropped and bare, with the mean atmospheric temperature for the week preceding each analysis.

quantities of carbon dioxide than the uncropped, but the authors think this is due to indirect effects. Passing from a neutral to a sour soil there was an increase in carbon dioxide, but different species of plants showed about the same production when grown on the same soil.

[19] Russell, E. J., and Appleyard, A. The atmosphere of the soil; its composition and cause of variation. *In* Jour. Agr. Sci., 7: 1–44. 1915.

These authors,[20] in summarizing the results of three years' work, conclude that the principal factors in carbon-dioxide production in the order of their importance are temperature, moisture, dissolved oxygen, and the growing crop. They obtained increased quantities of carbon dioxide on cropped soil, the two maxima occurring in May and August. The latter was the date of ripening. The authors argue that since little root activity occurs at the ripening period, the production of carbon dioxide can not be referred wholly to respiration. The authors did not find a depressing effect of the crop on carbon-dioxide production. Fred and Hart[21] compared additions of sulfates and phosphates and found in general the latter to be more effective.

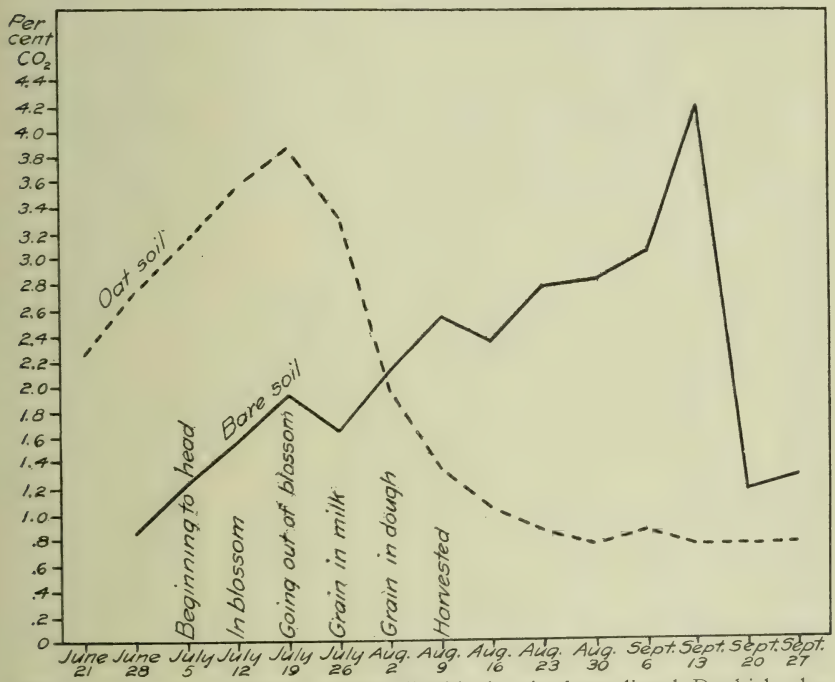

FIG. 14. Diagram showing carbon dioxide in air from limed Dunkirk clay loam, cropped and bare.

Potter and Snyder[22] treated soil with calcium carbonate, sodium nitrate, and ammonium sulfate singly and in combination. The car-

[20] Russell, E J., and Appleyard, A. The influence of soil conditions on the decomposition of organic matter in the soil. *In* Jour. Agr. Sci., 8: 385–417. 1917.

[21] Fred, E. B., and Hart, E. B. The comparative effect of phosphates and sulfates on soil bacteria. Wis. Agr. Expt. Sta. Research Bul. 35. 1915.

[22] Potter, R. S., and Snyder, R. S. Carbon and nitrogen changes in soil variously treated. *In* Soil Sci., 1: 76–94. 1916.

bonate increased the production of carbon dioxide, but the other materials did not. The effect of the calcium carbonate disappeared after 59 days.

The lack of uniformity in the results cited is no doubt due in large measure to the difference in conditions of the experiments and in the methods of determining the amounts of carbon dioxide produced. The evidence in the main points to the conclusion that fairly large quantities of carbon dioxide are excreted by plant roots, that this production reaches a maximum at the period of greatest vital activities, viz, the blooming period, and that it is increased by any factor which increases the vigor of growth of the plant.

Regarding the effect of lime and the reaction of the soil on carbon-dioxide formation, there seems to be little unanimity of opinion. The discrepancy may be due, as Lemmerman points out, to the absorption of the gaseous carbon dioxide when quicklime is applied and to the production of carbon dioxide by purely chemical means when cal-

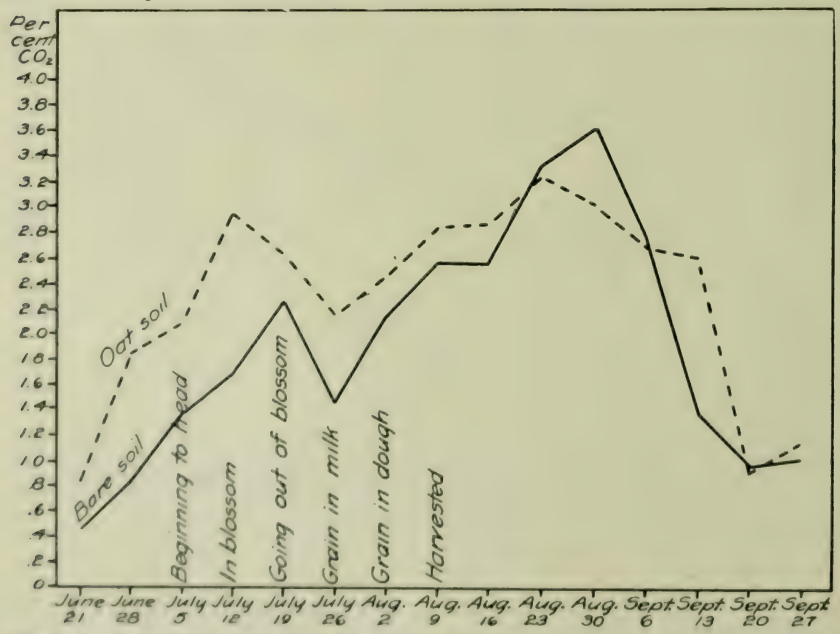

FIG. 15. Diagram showing carbon dioxide in air from unlimed Volusia silt loam, cropped and bare.

cium carbonate is added to acid soils. In either case the determination of carbon dioxide in the soil air by the methods described would not be a measure of carbon-dioxide production. In the experiments

to be described the results merely show fluctuations and not total carbon-dioxide production. These fluctuations were affected by so many uncontrolled factors that they do not necessarily parallel the production curves. However, interpreted in the light of these disturbances, the results show some interesting tendencies.

Methods.

The samples of air were collected from the drainage tubes at the bottoms of large lysimeter tanks, a description of which has already been published.[23] Each tank is slightly over 4 feet square and 4 feet

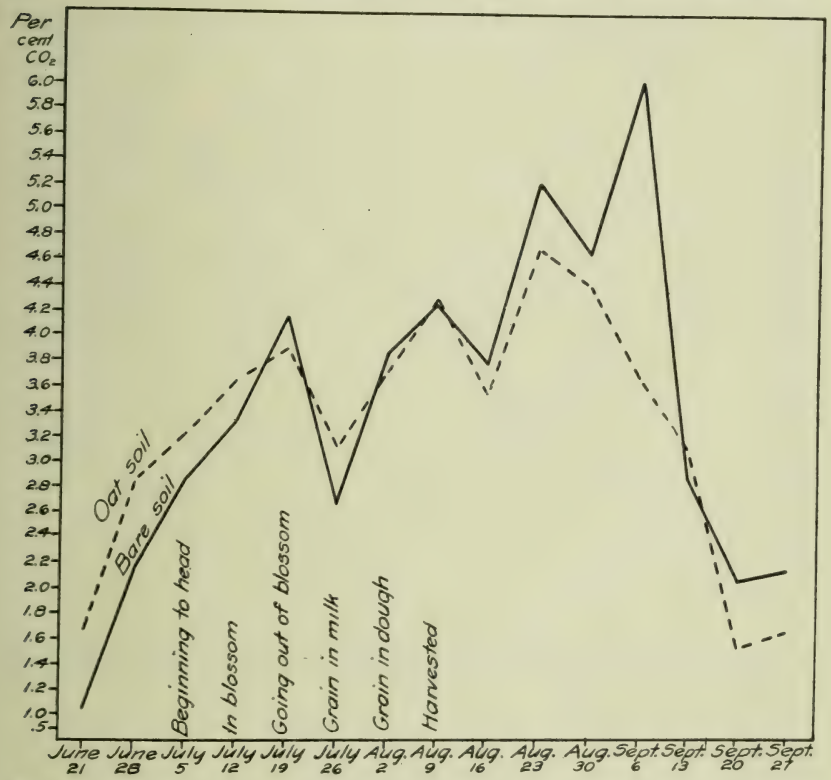

Fig. 16. Diagram showing carbon dioxide in air from limed Volusia silt loam, cropped and bare.

deep, with a capacity of about 3.5 tons of soil. They receive the natural rainfall but no other supply of moisture. Some of these tanks (1–12) were filled with Dunkirk clay loam soil in 1909 and the re-

[23] Lyon, T. L. Tanks for soil investigation at Cornell University. Science, n. s., 29: 621–623. 1909.

mainder with Volusia silt loam in 1910 (tanks 13–16) and in 1913 (tanks 20–21).

In collecting a sample of soil air a calibrated 500-c.c. Ehrlenmeyer flask was fitted with a 2-hole rubber stopper carrying in each hole a Geissler stopcock. One of these stopcocks was connected by means of rubber tubing to a 15-liter aspirator bottle. The other was connected in a similar way to a brass Y-tube and the latter to the drainage tube of the lysimeter. The remaining lower end of the Y-tube was connected to a rubber tube the lower end of which dipped under water. By this means it was possible to aspirate the air from the

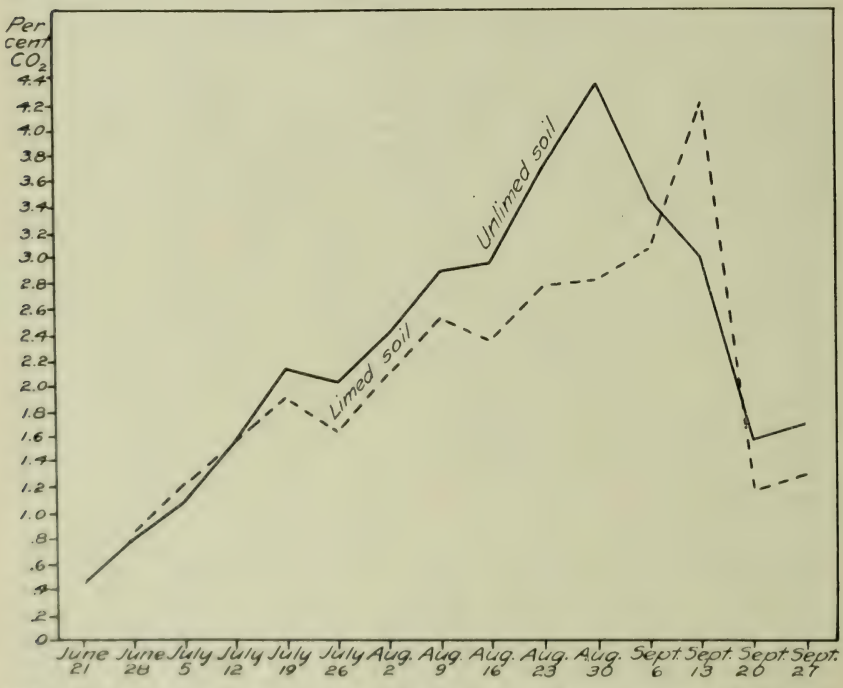

FIG. 17. Diagram showing carbon dioxide in air from uncropped Dunkirk clay loam, limed and unlimed.

lysimeter without interfering with the flow of drainage water. Soil air was drawn through the 500-c.c. calibrated flask until the atmospheric air in the latter was entirely displaced. It was found that emptying the aspirator bottle once was sufficient for this purpose. The flask was then disconnected, taken to the head house adjoining, and allowed to stand for a few minutes until the sample had risen to room temperature. The excess pressure inside the flask was relieved

by opening one of the stopcocks for a moment. Excess of standard barium-hydroxide solution was then added and the flask allowed to stand for 20 minutes with occasional shaking. The excess barium hydroxide was then determined by titration with standard oxalic acid solution.

Effect of Crop on the Carbon-Dioxide Content of Soil Air.

Determinations of carbon dioxide were made weekly from June 21 to September 27, 1916, in samples of air drawn from tanks 3, 4, 7,

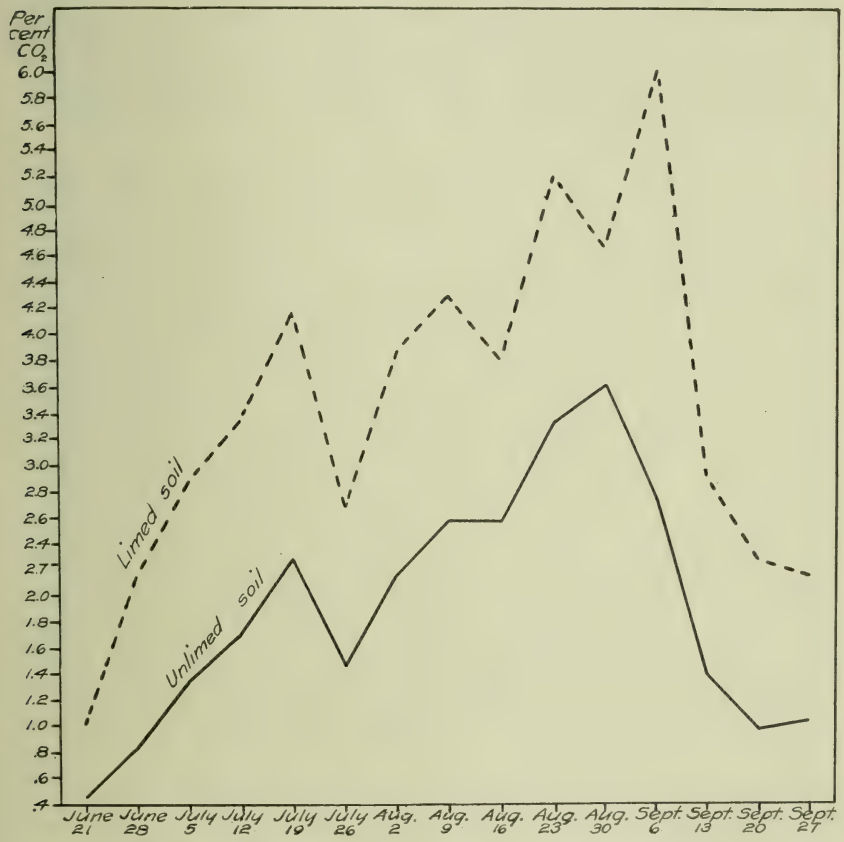

Fig. 18. Diagram showing carbon dioxide in air from uncropped Volusia silt loam, limed and unlimed.

8, 13, 14, 15, and 16, and the results plotted in curves shown in figures 13 to 16, inclusive. Tanks 7 and 8 received applications of 3,000 pounds per acre of quicklime in 1910 and 1915. Tanks 15 and 16 received one application of 3,000 pounds per acre of quicklime in

1913. Tanks 3 and 7 had been previously cropped as follows: 1910, corn; 1911, oats; 1912, wheat; 1913 and 1914, timothy; 1915, corn. Curves 1 and 2 admit of a comparison between Dunkirk clay loam cropped to oats in 1916 (tanks 3 and 7) and the same type of soil which had been kept bare of vegetation since it was put in place in 1909 (tanks 4 and 8). On June 21 the planted and unplanted tanks showed wide differences in the carbon-dioxide content. The cropped tanks showed a rapid increase up to the period of blooming, July 12–19, and then a rapid decline. The bare tanks showed a gradual increase, following in general seasonal variations and not reaching their maxima until August 30 to September 13. The fluctuations in the bare soil may be taken as representing bacterial action. After the maxima were reached there was a rapid decline both in the cropped and uncropped tanks.

As the ordinary diffusion of carbon dioxide from the soil with a lowering of percentage obtains at all times, a fall in the crop curve would result during a period of nonproductivity and hence would not necessarily represent an effect on the bacterial production. In this decline should the cropped soil curve fall considerably below the bare soil curve, the results are to be interpreted as showing some interference with bacterial activity. This is exactly what happened after August 2. On September 13, analyses of the air from the Dunkirk clay loam limed soil showed that the air from the cropped tank contained 0.75 percent carbon dioxide while that from the bare tank gave 4.2 percent. On August 30, the unlimed cropped soil showed a carbon-dioxide content of 0.85 percent, while the bare tank showed 4.3 percent. It may be objected that as the determinations of carbon dioxide represent that in the gaseous phase only and as the cropped soil undoubtedly contained smaller quantities of water, the larger amounts of carbon dioxide found would be due to a relatively smaller quantity in the liquid phase and therefore would not be indicative of relative production. It was not considered advisable to disturb the soil in order to obtain samples for moisture determinations, but there were unquestionably smaller quantities of water in the cropped tanks, as the following figures of the total drainage from these tanks from June 5 to November 1, 1916, show.

Tank 3, cropped	102.4 liters
Tank 7, cropped	94.4 liters
Tank 4, bare	306.0 liters
Tank 8, bare	280.0 liters

This objection might apply therefore to some extent to the figures

obtained prior to August 2, but on subsequent dates when the cropped tanks showed less carbon dioxide this factor could not have been predominant. In fact, if the smaller percentages subsequent to August 2 were influenced by the amount of moisture the depression due to cropping would be greater than is indicated by the curves.

Figures 15 and 16 permit a similar comparison on Volusia silt loam soil. Tanks 13, 14, 15, and 16 were filled in 1910 and had therefore been in place approximately the same period of years as had the Dunkirk clay loam. Tanks 14 and 16 had been kept bare of vegetation since being filled. Tanks 13 and 15 had been previously cropped as follows: 1913, oats; 1914, Canada field peas; 1915, corn. Comparing the cropped with the uncropped tanks, the curves are almost identical, markedly different from those obtained with the Dunkirk clay loam. It appears that the crop had little effect on the carbon-dioxide con-

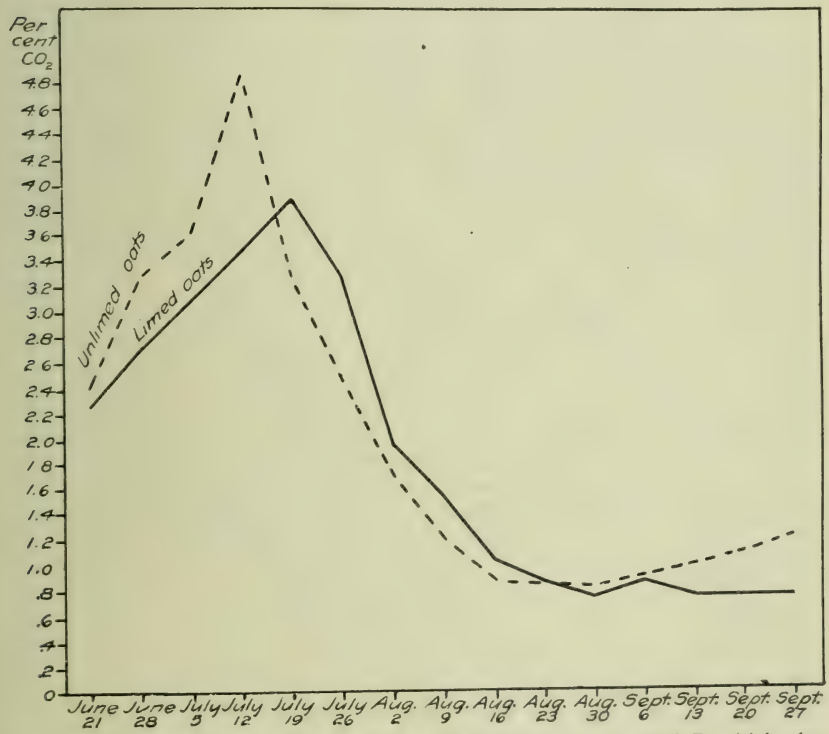

FIG. 19. Diagram showing carbon dioxide in air from cropped Dunkirk clay loam, limed and unlimed.

tent of Volusia silt loam. It is significant that crop growth on the Volusia silt loam was considerably less than on Dunkirk clay loam and it may be that the difference in carbon-dioxide production is in

some way connected with the vegetative activity of the plant. This idea is supported to some extent by the similarity between the curves of the two bare soils.

Effect of Quicklime on the Carbon Dioxide in Soil Air.

As previously stated, tank 8 received an application of 3,000 pounds per acre of quicklime in 1910 and a similar application in 1915. Tank 16 received 3,000 pounds per acre of quicklime in 1913. It is safe to assume that at the beginning of the season of 1916 all quicklime had been converted into calcium carbonate. The lime requirement (according to the Veitch method) of the surface foot of these soils before being placed in the tanks was approximately 3,000 pounds per acre. The soil in tanks 4 and 14 had never received an application of lime since being placed in the tanks.

Tanks 4 and 8 received 10 tons per acre of manure in 1910 and tanks 14 and 16 had the same quantity in 1913. By reference to figure 17, it appears that liming Dunkirk clay loam had little effect on

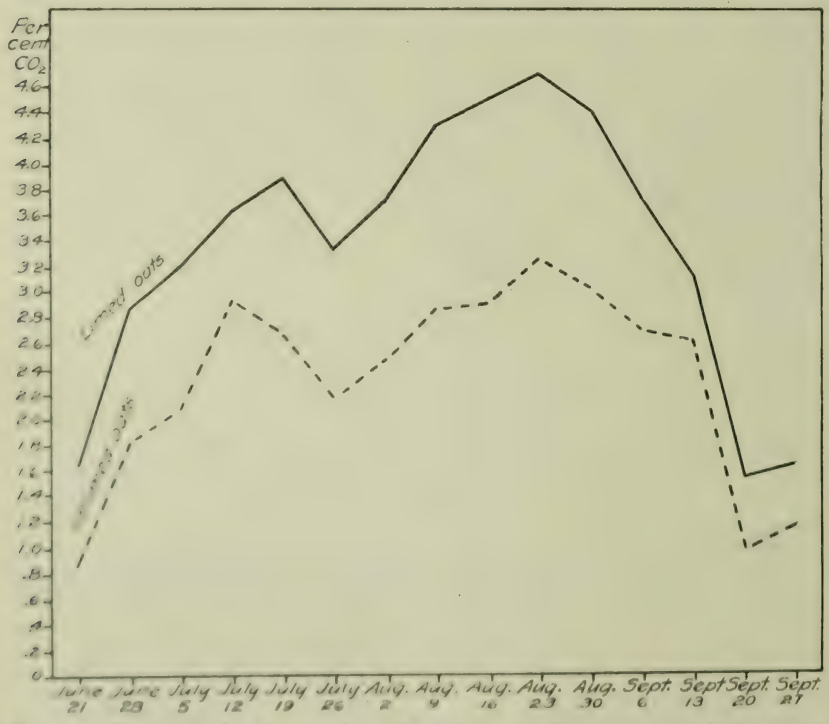

Fig. 17. Diagram showing carbon dioxide in air from cropped Volusia silt loam, limed and unlimed.

the carbon-dioxide content. The figures seem to indicate the usual seasonal fluctuations. The effect of liming on Volusia silt loam is quite marked (fig. 18). The curves for the limed and unlimed soils are approximately parallel at all periods, but the liming apparently had a markedly stimulating effect on bacterial activity. The same general relations are seen when the figures for the cropped tanks limed and unlimed are plotted (figures 19 and 20).

Liming did not increase the carbon dioxide in the air of cropped tanks of the Dunkirk clay loam, but had a decided effect on similarly treated tanks of the Volusia silt loam. It is significant that liming increased crop growth on the latter soil, while it had little effect on the Dunkirk clay loam. Volusia silt loam is a very heavy, compact soil and it is probable that the beneficial effect of line on the carbon-dioxide content is due mainly to an alteration of the physical condition rather than to its effect on the reaction of the soil.

Effect of Burnt Lime versus Limestone on the Carbon Dioxide of Soil Air.

Tanks 20 and 24 were filled with Volusia silt loam in 1913. On May 1, 1916, tank 20 received an application of 6,000 pounds per acre of quicklime and tank 24 received 12,000 pounds per acre of limestone, ground to pass a 50-mesh sieve. Oats were raised on both

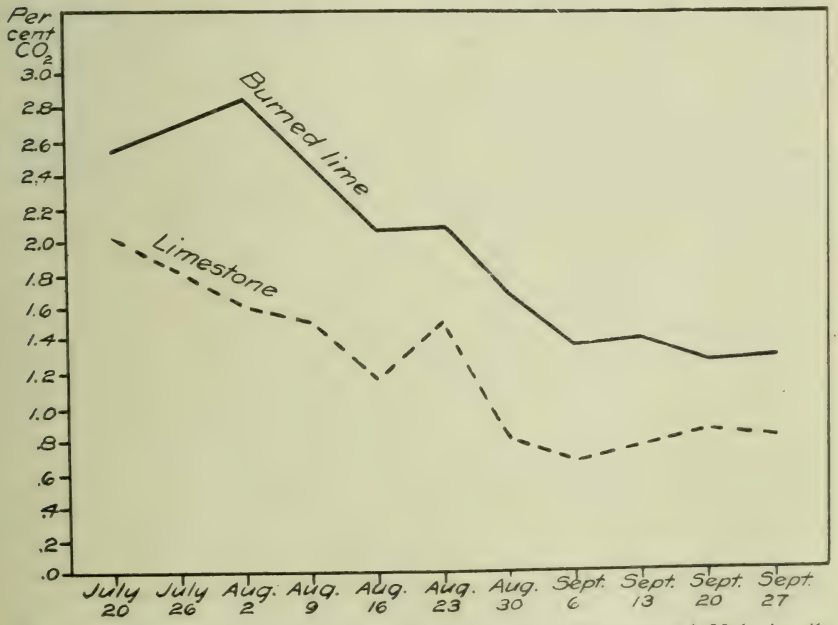

Fig. 21. Diagram showing carbon dioxide in air from cropped Volusia silt loam, limed with burnt lime and with ground limestone.

tanks. Figure 21 shows the results of carbon-dioxide determinations. Burnt lime gave larger quantities of carbon dioxide during the course of the observations (July 20 to September 27, 1916). The burnt lime curve is approximately parallel to the limestone curve. Both curves are similar to the cropping curves already discussed in that there is a decline after the period of greatest activity of the plant. Whether the burnt lime stimulated the bacteria to greater activity or whether the larger amount of carbon dioxide was due to a stimulation of the crop is not evident from the figures. The fact that the burnt lime tank yielded 931 grams of oats as compared with 842 grams from the limestone treatment lends support to the idea that the effect was due to greater crop growth.

Summary.

1. On Dunkirk clay loam cropping with oats produced striking fluctuations in the carbon-dioxide content of the soil air. The greatest apparent production was at the blooming period. Subsequent to the blooming period there was a marked decrease in the amount of carbon dioxide and this decrease was apparently due to the depressing effect of the crop on production by bacterial action. On Volusia silt loam the crop apparently had little effect on the carbon-dioxide content.

2. On Volusia silt loam addition of quicklime increased the amount of carbon dioxide in the soil air. This effect was noticed both on the cropped and uncropped tanks. On Dunkirk clay loam quicklime apparently produced no effect.

3. Treatment of Volusia silt loam with burnt lime was accompanied by larger production of carbon dioxide than was the treatment with a chemically equivalent quantity of ground limestone.

WHEAT-BREEDING IDEALS.[1]

HARRY SNYDER.

Wheat is the ideal bread cereal. The physical character of its proteins is such as to impart bread-making qualities, while the nature and variety of the amino acids of these proteins give the maximum food value. Wheat is worthy of the high position assigned it by Sir William Crookes in his presidential address before the British Association for the Advancement of Science in 1898, as "the most sustaining food grain of the great Caucasian race." Any improvement that can be effected in wheat is of the greatest benefit to mankind.

The early history of wheat is shrouded in mystery. Presumably somewhere in Mesopotamia where modern man was nurtured, wheat had its origin. It has been stated that if wheat were not seeded and garnered by man it would soon become extinct, since it cannot exist as a volunteer crop. It would seem that man, in recognizing the great value of wheat as food, had taken in hand its propagation, and that nature had intrusted to him its care since it has lost the power to fend for itself.

Some of the greatest of men have taken a deep interest in wheat improvement. General Washington, while active in the war for independence, had time to think of wheat. In one of his letters he says: "The wheat from some of my plantations by one pair of steelyards will weigh upwards of 60 pounds, and better wheat than I now have I do not expect to make." Referring to this same wheat some years later he wrote: "No wheat that has ever yet fallen under my observation exceeds the wheat which some years ago I cultivated extensively, but which from inattention during my absence of almost nine years from home, has got so mixed or degenerated as scarcely to retain any of its original characteristics properly."

During its thousands of years of domestication, wheat must have undergone some changes in both botanical structure and chemical composition, and it would seem that its development should be continued and that it be still farther improved.

[1] Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917. The author of this paper is chemist for the Russell-Miller Milling Co., Minneapolis, Minn.

Seed selection and production upon rich suitable soils with favorable climatic conditions have heretofore been the chief factors for improving the crop. But other important ways beside seed selection and proper nutrition are now open to us for the improvement of wheat, such as the selection and breeding of the parent wheat stocks. Parenthood in wheat is a factor for either improvement or retrogression, as it is in any life process. I feel too incompetent to attempt to discuss any of the general laws of heredity as they apply to wheat, but I wish to note certain characteristics or properties of wheat, which it would seem should receive more attention in wheat breeding.

It is always desirable to have in mind definite ideas as to what is desired to achieve in plant breeding, but it is particularly so in the case of wheat. The wheat breeder aims to secure new wheats or to improve old strains along one or more of the following lines:

1. Large yield.
2. Stiffness of straw.
3. Resistance to rust and other diseases.
4. Early maturity so as to escape heat, frost, and rust damage.
5. Improved bread-making qualities and higher food value.

The importance of maintaining and improving the quality of wheat deserves particular attention from the wheat breeder. It is not accomplishing enough to secure a new wheat showing a larger yield per acre, if it is at a material sacrifice of the quality of the crop, when it is possible to secure a gain in both yield and quality. As a scholastic proposition, yield and quality might seem antagonistic characteristics, so that you could not expect to secure one without some sacrifice of the other. Happily the work of the late Dr. Saunders in developing the Marquis wheat shows that it is possible to secure both quality and yield as well as early maturity and hardiness. Since it has been proven possible to accomplish such results, I believe more attention should be given to improving the quality of wheat.

Ideas vary as to what is meant by wheat quality, which is a more or less indefinite term difficult to state with mathematical exactness. Quality cannot be expressed in percentage figures of special constituents. It is the bread maker and the housewife who are the final judges. If the wheat is of such character that the flour milled from it can be made into good bread, then the wheat is of good quality. The miller and the baker can assist in developing latent wheat quality, but they cannot create or impart it when it does not exist. It is much the same as with butter, if it is pleasing in taste and appearance it is of good quality. Neither wheat quality nor butter quality is as yet

capable of being determined absolutely by chemical analysis. Although wheat quality is difficult to measure, certain physical characteristics can be taken as a general index of quality and they will be found helpful to the wheat breeder. For example, a high protein content is very desirable provided the protein is in such forms as to impart the best physical characteristics for bread-making, such as a certain degree of plasticity of the gluten. Hence, quantity and quality of the gluten are a helpful guide to the wheat breeder. Many times, however, the wheat crop is hampered in showing its capabilities as to protein production because of lack of available nitrogen or other plant food. Seasonable variations also sometimes handicap the wheat breeder in arriving at conclusions. Wheat that is of fair glutenous character one year may be starchy another year, and some years the strongest glutenous wheats develop starchy tendencies. While these variations and handicaps are known to exist and must be recognized, certain general principles will be found helpful and can be applied by the wheat breeder.

Suppose the wheat breeder has before him two samples of wheat of similar general character that have been grown and observed under like conditions, and their performance records are quite the same. He wishes to give preference to the one having maximum quality. In one sample, *A*, there are 80 percent of dark amber corneous or glutenous kernels and 20 percent that tend to be light colored and starchy; tests show the glutenous kernels to contain 16 percent protein and the starchy ones 12 percent. In sample *B* there is approximately the same ratio of glutenous and starchy kernels, but the analyses show 14.5 and 11 percent of protein for the two types of kernels. Naturally the preference would be given to the selected kernels of sample *A*, as the type of harder, stronger, and presumably better wheat. The selection, however, should be made not only on the basis of the amount of protein, but due regard should be given also to the physical quality of the gluten. If the gluten from the hard, selected *B* wheat is of the requisite plasticity and of superior quality to that of *A*, then preference should be given to *B*, as a crop from such seed will give the better bread-making value. The rule for selection should be: Get all the protein or gluten you can in the wheat, provided the gluten is of such character as to impart maximum bread-making quality. A high gluten with rather poor bread-making value is a poor combination. To breed wheats with the view of securing the maximum protein without regard to bread-making value is not working along right lines.

In some wheat-breeding work it has been the aim to secure immunity from rust and other diseases. The usual theory is to select as parent stock the most promising wheats as to powers of rust resistance. In some cases a selected durum has been taken as one of the parents. Particular attention must then be given to the other parent, because durum does not impart desirable bread-making qualities. Rust resistance is also obtained indirectly by early maturity. Hence, an early-maturing variety of high quality is more desirable than a later rust-resistant one of poorer quality. It takes time to produce a good wheat by breeding alone, hence more progress will be made when the time element is considered by seed selection from well-established varieties rather than by premature attempts to replace old, well-known types with new and questionable kinds. When a community has established a reputation for producing a wheat of quality the maximum price with a special premium is paid for such wheat. When the wheat is of poor or mediocre quality its marketing is attended with difficulties unless there is a general wheat shortage, when a poor quality commands an abnormal price. This principle of not encouraging the introduction of a poorer wheat where a community has established a reputation for raising the best quality of wheat is recognized by Dr. Saunders in his recommendations in the distribution of his Preston and Marquis wheats.[2]

> Preston, Huron, and Stanley, by careful selection, have been considerably improved; however, they do not produce flour of the highest baking strength, a disadvantage the seriousness of which can easily be exaggerated, but should not be overlooked in those districts where wheat is grown for export, and where a reputation for remarkably high baking strength has already been established. This applies particularly to the central parts of Canada. . . . Taking all points into consideration, Marquis wheat is recommended as the most promising sort at present available for farmers who require a hard, red wheat of high baking strength and ripening earlier than Red Fife.

The production of an inferior quality article in a locality where a reputation has been established for superior goods is more serious than might appear at first consideration. About 1870 the Mohawk Valley of New York produced a superior quality of cheese that commanded a premium in the English markets. A few years later the doctrine of combined cheese and butter production was promulgated. It was argued that the milk could be skimmed a little and the cheese still be just as good, while both cheese and butter could be made and sold. Just about that time the Canadian cheese industry started, and they did not skim, but made cheese only. As a result the Mohawk

[2] Saunders, C. E. *In* Canadian Expt. Farms. Rpt., 1910, p. 171. 1911.

Valley cheese lost its English market, which was won by Canadian full-milk cheese. Following this loss of the cheese market many farms declined in value from $10 to $20 per acre. It is sometimes difficult for an agricultural community to change its procedure and the loss of a good market for a staple product is a serious matter. A reputation for a quality product is a valuable asset for any community. After the war is over, and Kaiser "kultur" is discredited as it deserves, wheat culture will return to normal conditions; wheat will cease to be a war-stimulated industry and it will then become a world-competitive industry where quality will be an important commercial factor.

In the promulgation of new wheats that are lacking in high bread-making qualities but otherwise possess desirable characteristics it is a mistake to argue that the miller is prejudiced against the wheat and that he is not willing to accept it at its face value. The miller, as a rule, is only too glad to get wheat of quality, and he is not liable to be mistaken in his judgment of a new wheat unless he mills and markets only a small quantity of it. A heavy-weight, good-appearing, but poor bread-making wheat may form a small part of a wheat milling blend and not show its poor quality as readily as would be the case if the new wheat alone were milled in quantity. It is a real test of a wheat-breeder's character when he recognizes the defects of a good-looking wheat that proves to be only a mediocre bread-maker. Happily there are such scientists, as the quotation just cited from Dr. Saunders shows.

In testing new varieties of wheat, the small 2-roll sample mill will be found helpful if properly used and attempts are not made to solve milling problems that are not capable of being approached with such meager facilities. A small, so-called experimental mill will enable a sample to be prepared for testing the amount and physical quality of the gluten, and in a general way to tell if the wheat is likely to yield a flour that is reasonably responsive to yeast action. If a wheat passes such a test then it has reached a point where it can be tried in a large way and enough produced for trial in a small but reasonably well-equipped commercial mill. The wheat will finally be measured by regular commercial standards and the sooner a wheat breeder has submitted his new wheat to such a test the better position he is in to judge of the quality of his new product. To attempt to put out a new wheat with insufficient testing as to its quality or to cover up a defect is, to say the least, unscientific, as any shortcomings a wheat may possess are sure to be discovered when put to the test.

The small sample mill cannot be used for determining the flour yield of a wheat or for some of the finer points in connection with flour qualities. There are no short cuts in flour milling, that is, no important operations can be abbreviated or omitted and at the same time a quality flour made. The final test of a wheat must be its deportment under commercial conditions. I do not wish to discourage the use of the sample mill, but to encourage its proper use in wheat breeding.

The bulletins and circulars issued by one of the experiment stations the past year give some interesting data on the comparative workings of the sample or experimental mill and a small commercial mill. Some of the same wheats were milled both experimentally and commercially. Calculations from the published data show that a bushel of the same wheat yielded on the sample mill 5 pounds more flour and 25 percent less feed, with 2 pounds per hundred more of invisible loss than from the commercial mill where the flour was much superior. The sample mill fails to make a proper separation between the feed and the flour. When you check the workings of a small sample or experimental mill against a well-equipped commercial plant many amusing inconsistencies appear that would not be apparent to the layman. Flour milling is a high-grade mechanical industry, and the plant breeder should call upon the miller for expert assistance in this line rather than attempt to become a miller in addition to being a plant breeder. Cooperation upon such questions is the best way to get results.

There are many important side lines or problems which the wheat breeder can take up in connection with his regular work, and which have an important bearing upon the main line he is investigating. The tendency of wheats to become starchy or to develop what is sometimes called yellowberry is one of these problems. While it appears to be due in part to climatic conditions, it is also due to lack of available plant food, particularly nitrogen, as well as to other causes.

For a time some believed that wheats grown on irrigated lands were necessarily starchy in character, but of late years it has been found that wheat of very high quality can be raised by irrigation with proper control of the water supply. The problems of plant food, water supply, and quality of crop are open for further investigation.

Fungous diseases give the wheat breeder additional problems to contend with. The value of formaldehyde as a general fungicide appears to be well known, but many farmers have not as yet been sufficiently impressed with the fact that it is possible to use so strong a

solution as to impair seed germination. During the past year my attention has been called to cases where large losses from overtreatment have resulted. It is not safe to conclude that if a definite strength of formaldehyde solution is good, a larger amount would be better.

National grading will doubtless prove valuable in gradually raising the quality of wheat. When each State and market had different rules for grading, it not infrequently happened that a wheat receiving a No. 2 grade in one market or State would get a No. 1 grade in another, or vice versa. This lack of uniformity has led to serious misunderstanding and trouble. The marketing of clean grain needs to be encouraged. More fanning mills should be used on farms, then less valuable transportation space would be required for marketing the cleaner wheat and the screenings could be fed to live stock on the farms. It never pays to market a dirty product and this applies particularly to wheat. The national grading of grain must necessarily recognize the commercial characteristics of the grains graded, which cannot be based on an imperative academic basis. Any attempt to make it appear that wheat is always wheat and that all weights, kinds, and types are equally valuable for flour and bread-making purposes simply encourages poor, slovenly methods of farming.

The wheat breeder should encourage wheat farmers to produce and disseminate the best varieties of wheat. Seed-wheat farms where high-grade pedigreed wheat is produced are as necessary as stock farms where pedigreed stock is raised. By improving jointly the yield and quality of wheat the wheat breeder renders an important service to mankind. The best of bread-making wheats selected so as to have the maximum protein need little or no supplementing with other more expensive protein-containing foods. The best results are secured from a liberal mixed diet, though good bread that is rich in protein supplies at a minimum cost the maximum of nutrients.

NATURAL CROSS-POLLINATION IN WHEAT.[1]

H. K. Hayes.

Introduction.

The pure-line method of breeding has been almost universally adopted for self-fertilized crops. The initial selection is generally considered simply to isolate those types which are present in the commercial variety. Continuous selection in pure lines of self-fertilized crops has not, as a rule, given any improvement of importance, although a few cases are on record of a sudden change in a pure line which proved to be of selection value. Almost all commercial varieties of farm crops are mixtures of various types. Even though all plants are of the same general appearance, selection often isolates types which differ in such important things as yield and resistance to lodging.

As an illustration of the results of such selection, the production of Haynes Bluestem wheat, Minnesota No. 169, may be mentioned. Before the recent introduction of Marquis wheat, this pedigreed type was widely grown in Minnesota. Minnesota No. 169 was one of a large number of selections which were first tested at the Minnesota station in 1892. The initial selection was a single plant which gave progeny of promise and which, when tested in various parts of Minnesota, gave a marked increase as compared with the commercial types then grown.

Minnesota No. 169 is a hairy-chaffed, awnless wheat with red coloring matter in the bran layer of the kernel. An examination in 1915 of bulk seed of this strain showed the presence of some unpigmented or white kernels. These white kernels bred true to the Bluestem type of plant for other characters. Several samples of Minnesota No. 169 as grown by farmers were obtained in 1916 and were examined. Nearly all of these samples contained some white kernels which, when grown, proved to be similar to Haynes Bluestem in other characters.

If Bluestem wheat was originally pure for the red color of the kernel, which seems very likely, the question at once arises as to

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whether the presence of white kernels is due to crossing or to a loss mutation. In either case the breeder is faced with the necessity of purifying the type and one naturally wonders how frequently it will be necessary to repurify a "pure" line.

It seems reasonable to suppose that natural cross-pollination may be a frequent cause of the production of inherited variations within pure lines. If there is much cross-pollination, a careful examination of nursery plots would seem the best possible means for determining the frequency of the occurrence, for under these conditions many different types are being grown at short distances from each other.

Previous Studies of Natural Cross-Pollination in Wheat.

For a detailed discussion of studies in this field, the reader is referred to a review made by Pope (1915).[2] Some of the more important work along this line may be briefly repeated. Nilsson-Ehle (1915) was able to show by an experimental test that some varieties are much more liable to natural cross-pollination than others.

Only a few cases of cross-pollination have been recorded in North America. In 1903 Saunders (1905) announced a single case of a natural hybrid. Smith (1912) found eight natural hybrids in 96 rows of Turkey winter wheat. More recently, Leighty (1915) has described four cases of natural crosses between wheat and rye, and concludes that the existence of such hybrids indicates that wheat is more often cross-pollinated than was formerly supposed.

Results at the Minnesota Station.

In 1915, nursery plots of Haynes Bluestem wheat were grown as checks for the purpose of determining the variability of the field used for the nursery work. Plots of 100 plants, placed in the form of a square, were used at this time. The Bluestem plots were placed every fifth plot and at maturity a number of individual plants were selected for the purpose of producing pure lines of Bluestem.

Fifty of these plants were grown in 1916 in individual plots. Of these 50 types, 3 proved definitely that they were natural hybrids and gave ratios which were according to Mendelian expectation; 1 gave 45 brown and 19 white chaffed plants; another gave 32 hairy brown chaff, 16 hairy white chaff, 13 smooth brown chaff, and 5 smooth white chaff plants; the third gave 46 hairy and 19 smooth chaff plants. Two other of the Bluestem selections gave both red and white kernels.

[2] References are to "Literature cited," page 122.

Forty-seven plant selections of Marquis were grown in 1916 from selections made in field variety test plots. Of these all were true for the Marquis type of head, but two gave both red and white kernels. Thirty-four other pure lines were grown from individual plants, no natural hybrids being observed.

In the winter wheat nursery, 54 selections were carefully examined; of these, one proved to be a natural hybrid and gave definite segregation ratios.

Approximately 100 individual plant selections of spring wheat were made in 1916 in the nursery and were grown in 1917. No segregation occurred, although four plants were discovered which were believed to be F_1 crosses. It is a comparatively easy matter to tell a first-generation cross between Marquis or Bluestem and any bearded variety of wheat, because the first generation has awns which are intermediate in length.

Thirty-six selections of types which were of promise in 1916 were tested in rod rows in 1917. Two rod rows of each selection were carefully examined to determine any impurities. Of these 36 plots, 21 had from one to eight plants that were clearly first-generation crosses.

Conclusion.

The results here reported would indicate that conditions in 1915 and 1916 at University Farm were either very favorable for natural crossing in wheat or that its occurrence is much more frequent than has been generally supposed to be the case.

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NORMAL SELF-FERTILIZATION IN CORN.[1]

H. K. HAYES.

INTRODUCTION.

Methods of breeding self-fertilized plants have been standardized so that at the present time the same general plan is used by nearly all scientific investigators. Many minor points are not yet entirely settled, but these are of relatively little importance. With corn, however, there is little uniformity of opinion among plant breeders as to the actual value of different methods of work. With regard to the correlation of various ear and plant characters and resultant yield of the progeny a large amount of data shows that there is no significant relation. This lack of correlation between ear and plant characters and yield of progeny in corn is partially explained by the fact that environmental effects modify various ear and plant characters to a marked degree. The mode of pollination of the corn plant may be given as a second cause of this lack of relation.

Studies by East (1908, 1909),[2] Shull (1908, 1910), Collins (1910), and others, together with further data, have been reviewed by East and Hayes (1912). One of the conclusions reached as a result of these investigations was that self-fertilization in plants that naturally cross-pollinate reduces vigor and cross-pollination in self-fertilized plants tends to increase vigor. It was believed that this phenomenon of increased vigor in first-generation crosses, which has been called heterosis by Shull, was a physiological stimulus due to heterozygosis, although it was recognized that some factors in the heterozygous condition gave a greater stimulus to development than others. A recent hypothesis of Jones (1917) is very attractive and places the matter on a strictly inheritance basis. He attributes the increased vigor which is often obtained in the heterozygous condition to growth factors. This seems logical, as nearly all experiments show that the heterozygous condition for each particular growth factor gives more than half as great a result as the homozygous condition. While dominance is not complete, there is almost always a tendency to

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[2] References are to "Literature cited," p. 126.

dominance. The hypothesis of linkage is used to explain why it is impossible to obtain all growth factors in a single homozygous individual.

Effects of Self-Fertilization on Yield in Corn.

Previous investigators have shown that the first year of self-fertilization in corn often causes large reductions in vigor. As a contribution to the question of the actual amount of reduction in yield due to such fertilization the following comparison of the yields of normally pollinated Minnesota No. 13 yellow dent corn and 15 first generation self-fertilized lines is given.

Table 1.—*Yield in bushels per acre of normally pollinated Minnesota No. 13 corn and 15 first generation self-fertilized lines.*

Variety.	Mode of pollination.	Yield, bushels per acre.	Variety.	Mode of pollination.	Yield, bushels per acre
Minn. 13	Normal	49.3	13–46	1 year selfed	12.3
13–9	1 year selfed	15.4	13–31	do.	25.2
13–12	do.	14.8	13–47	do.	25.8
13–17	do.	34.2	13–56	do.	29.4
13–19	do.	18.7	13–78	do.	28.4
13–25	do.	20.1	13–99	do.	7.9
13–30	do.	43.1	13–199	do.	24.3
13–34	do.	19.4			
13–35	do.	41.0	Average selfed lines.....		24.0

The normally pollinated Minnesota No. 13 gave a yield of 49.3 bushels, while the average of the selfed lines gave a yield of 24.0 bushels. This is slightly more than a 50-percent decrease in yield for the self-fertilized as compared with the normally pollinated seed.

The amount of normal self-fertilization is, therefore, of interest. A preliminary study was outlined at Minnesota and started in 1916 with the purpose of determining the percentage of normal self-pollination under Minnesota conditions.

Previous Studies.

Waller (1917) has recently reported preliminary results as obtained at the Ohio station. He used yellow and white dent varieties of corn and planted hills of three stalks each of Wing Hundred-Day White in a field of Reid Yellow Dent. The hills of Wing white dent were placed at some distance apart and before pollination two of the three stalks from each hill of the white corn were detasseled. The percentage of white kernels was then determined for each ear of each stalk of the white corn upon which a tassel was allowed to remain. There was found to be considerable difficulty in separating the white

and yellow seeds. An average of 5.13 percent of self-pollination was obtained from these tests.

Results of this nature would be of almost enough value to pay all seedsmen and farmers to use seed from detasseled rows, thus insuring cross-pollination. This method has been encouraged by the Illinois station (Hopkins et al., 1905).

As Waller has pointed out, a number of experiments will need to be made before definite conclusions as to normal self-pollination can be reached.

Results at the Minnesota Station.

In the Minnesota test, Rustler white dent and Minnesota No. 13 yellow dent were used. Single seeds of Rustler white dent were planted in hills at some distance from each other and a stake was placed beside each white seed. Due to various causes only six ears grown from the white seeds were obtained. The resultant progeny were then carefully examined and a separation was made into three groups, yellows, doubtful yellows, and whites. It was found to be very difficult to separate the seeds, although great care was made to place only those seeds with some yellow color in the endosperm in the yellow group. The result of this classification is given in Table 2.

Table 2.—*Yellow, doubtful yellow, and white seeds obtained from ears of Rustler white dent grown in a field of Minnesota No. 13 yellow dent corn.*

Ear No.	Yellow.	Doubtful yellow.	White.
1	395	22	6
2	335	20	7
3	179	23	16
4	396	35	10
5	361	101	27
6	245	28	3
Total.....	1,911	229	69

The following year a number of hills of the doubtful yellow and white groups were grown and approximately 25 ears from each group were artificially self-fertilized. All of these ears at maturity contained a considerable percentage of yellow seeds, which proves that nearly all seeds were cross-pollinated the previous year.

If the classification had not been tested the whites would have been considered pure white and the doubtful yellow and yellows would have been considered yellow. This shows the impossibility of correctly classifying seeds of crosses between yellow endosperm dent and white endosperm dent varieties of maize without determining the degree of error in the classification.

Conclusions.

The results here reported appear to justify the following conclusions:

1. The first year of self-fertilization in maize, on the average, causes a reduction of about 50 percent in vigor as determined by the yield in bushels of shelled corn per acre of normally pollinated and self-fertilized strains of Minnesota No. 13 dent corn.

2. If there is normally as high as 5 percent of self-fertilization under field conditions, it might pay seedsmen and corn growers to use seed from detasseled stalks, thus using only cross-pollinated seed.

3. The amount of normal self-pollination under field conditions as determined by a somewhat limited test proved to be certainly less than 5 percent. These results, although too few to base conclusions upon, are here given with the hope that other investigators will make similar tests.

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MINERAL FOOD REQUIREMENTS OF THE WHEAT PLANT AT DIFFERENT STAGES OF ITS DEVELOPMENT.[1]

A. G. McCall and P. E. Richards.

Introduction.

Two years ago in a brief paper published in the Journal of this Society[2] the senior author called attention to the desirability of a careful study, under controlled conditions, of the mineral food requirements of the principal farm crops plants at different stages of their development, with a view to working out the fundamentals of a rational fertilizer practice. In this original publication and in a subsequent paper in Soil Science[3] the method of attack of this problem is described. In addition to describing the method, the last-mentioned paper gives the results for the first 24-day growth period for wheat.

In a paper read before the Society for the Promotion of Agricultural Science and printed in the Proceedings of that Society for 1916,[4] the senior author has shown that the ratio of mineral nutrients giving the best growth rate for this early period is practically the same for the soybean as for the wheat plant. During the past year the work has been extended to cover three stages in the development of the wheat plant; namely, the first 30 days, the second 30 days, and finally the period extending from the close of the second 30-day period to the maturity of the plant.

Method of Experimentation.

The salts employed in making up the nutrient solutions were monopotassium phosphate, calcium nitrate, and magnesium sulfate. Thirty-six different proportions of these salts were used, thus neces-

[1] Contribution from the Department of Soils of the Maryland Agricultural Experiment Station, College Park, Md. Presented by the senior author at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 12, 1917.

[2] McCall, A. G. A new method for the study of plant nutrients in sand cultures. *In* Jour. Amer. Soc. Agron., 7: 249–252. 1915.

[3] McCall, A. G. The physiological balance of nutrient solutions for plants in sand cultures. *In* Soil Science, 2: 207–253. 1916.

[4] McCall, A. G. The physiological requirements of wheat and soybeans growing in sand media. *In* Proc. Soc. Prom. Agr. Sci. for 1916, p. 46–59. 1917.

sitating the growing of 36 different cultures for each of the three growth periods. Since the dry weight was used as a measure of the growth rate during the different periods, it was of course impossible to carry through to maturity the same individuals. According to the plan adopted, the first series of cultures were grown for a period of 30 days, when they were harvested and the dry weights determined. A second series of cultures were then started from the same lot of seed as that used for the first series. During the first 30 days these plants of the second series were given a nutrient solution containing the same proportion of the three salts as had been found to give the best growth rate during the first growth period. From the close of the first 30-day period to the end of 60 days the individual cultures of the second series were supplied with the same different proportions of the three salts as was employed in the first series. At the end of 60 days the second series was harvested and from the dry weights the best proportion of salts for the second period was obtained. In a similar manner the plants for the third series were grown from the same lot of seed and supplied with the best salts proportions during the first and second periods, after which they were given the differential feeding and harvested at maturity.

The growth period for Series I extended from October 10 to November 11, 1916; Series II from December 18, 1916, to February 17, 1917, and Series III from March 14 to June 25, 1917. Plates 2 and 3 show the appearance of the plants at the end of these growth periods. The seed used was northwestern grown spring wheat of the Marquis variety obtained from the Olds Seed Co., Madison, Wis. Spring wheat has proven to be much more satisfactory than winter wheat, since under greenhouse conditions the former develops a stiffer straw and is less difficult to bring to maturity than the latter.

The plants were grown in pure washed quartz sand, the culture pots being arranged on rotating tables, in order to obtain uniformity in external environmental conditions. In the earlier work granite-ware pots were used, but during the past year clay pots have been employed, in order to avoid bringing the nutrient solution into contact with soldered joints. The form of the pot which is now being used and the method of supporting the plants are shown in Plate 3. Figure 22 is a cross-section view of the pot and shows the arrangement of the supply funnel and the outlet tubes.

In order to make the containers impervious to moisture and at the same time prevent the solution from coming into contact with the clay, the pots were first boiled in paraffin to drive the air out of the walls and then brushed over both inside and outside with a thin coat

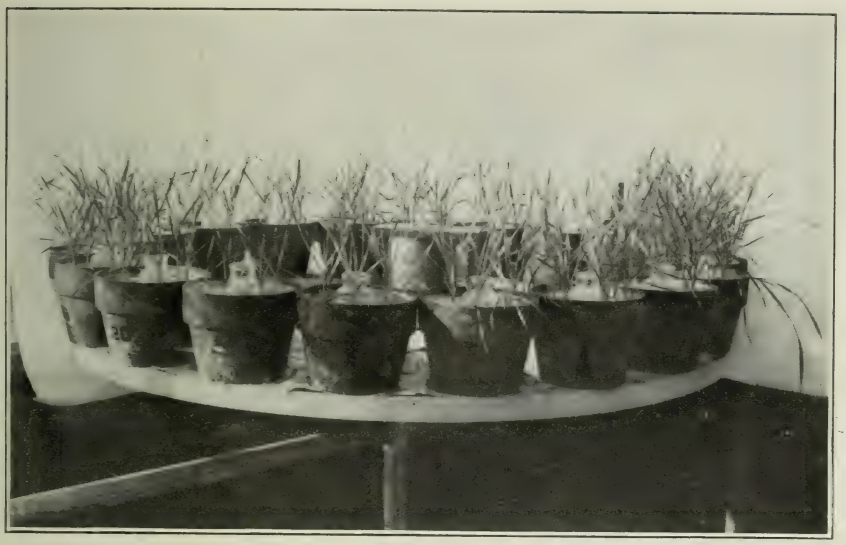
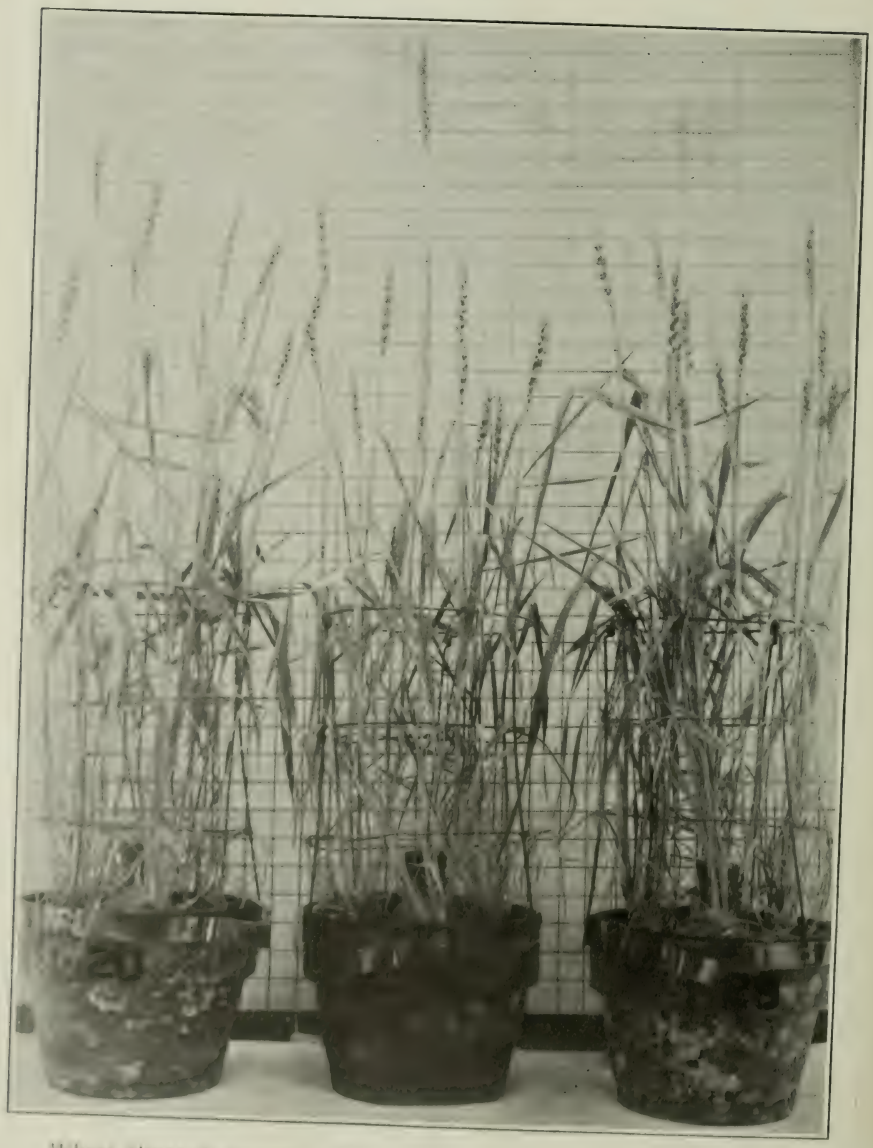


FIG. 1. Rotating table used to secure uniformity in external environment for wheat cultures.

FIG. 2. Wheat plants at the close of the second 30-day period. The plants are supported by an open wire frame which permits the leaves to assume a natural position.



Wheat plants at maturity. The screen at the rear has one-inch mesh.

of hot paraffin. The glass funnel (*D*) rests on an inverted glazed porcelain dish (*F*) which not only supports the funnel but also serves to insure a more thorough distribution of the solution throughout the mass of sand. The glass outlet tube is held in place by a paraffin seal (*B*) and has its inner end resting on the bottom of the pot near the center. The bell-shaped enlargement (*H*) at the end of this tube is closed against the entrance of sand by the insertion of a plug of glass wool. A short length of glass tubing inserted ahead of the wool effectively provides against the possibility of the plug being drawn out when suction is applied for the removal of the solution. The substratum used in these cultures consisted of medium fine white sand which has been washed several times with distilled water from a Barnstead still. The weighed quantity of dry sand was first placed in each pot and then thoroughly washed several times by covering the surface with distilled water and drawing the liquid down through the sand by means of suction applied to the outlet tube. Failure of the control cultures to develop in the sand supplied only with distilled water instead of the nutrient solution was sufficient evidence that the washing was adequate to remove any plant nutrients that might have been present in the unwashed sand. The salts used in making up the culture solutions were Baker's "analyzed" monopotassium phosphate and calcium nitrate and Merck's "blue label" magnesium sulfate. Stock solutions were made up by dissolving gram molecular weights of these salts separately in a liter of water. Before making up the final nutrient solutions the stock solution was diluted to one fourth molecular and stored in flasks which were connected with automatic

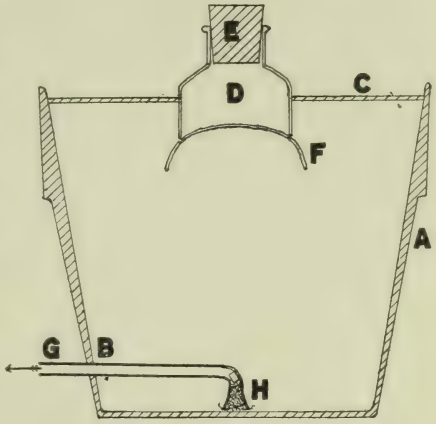


FIG. 22. Cross-section view of the clay pot used for sand cultures. *A*, paraffined clay wall; *B*, paraffin seal; *C*, wax seal covering surface of sand; *D*, supply funnel made by cutting bottom out of a wide-mouthed bottle; *E*, cork stopper; *F*, inverted porcelain dish; *G*, point of attachment to suction line; *H*, inner end of suction tube which is protected against the entrance of sand by means of a plug of glass wool. Note the short length of glass tubing at the bend. This effectively prevents the glass wool from being drawn over when suction is applied.

burettes through which the required amount was drawn each time a new set of nutrient solutions was to be prepared.

In each series 36 cultures were employed, each of which received at the end of each successive 3-day period a culture solution having a total osmotic concentration of 1.75 atmospheres. The solution supplied to each particular culture differed, however, from that supplied to the other cultures in the series, with respect to the proportions of the three component salts. At the end of each 3-day period the pots were weighed and brought back to their original weight by the addition of distilled water. The nutrient solutions were then removed from the pots by suction applied to the outlet tubes and a fresh solution supplied through the inverted funnel at the top, thus insuring an approximately constant total concentration.

Discussion of Results.

ARRANGEMENT OF THE CULTURES.

For convenience in designating the individual cultures and to give clearness to the discussion, the cultures have been grouped in the form of an equilateral triangle as has been done for similar series by other writers. These groupings are shown in triangle A of figure 23, in which the individual cultures are represented by circles. It will be seen that the lower row has eight cultures and that as we proceed upward each row has one culture less than the one below, the eighth row containing but a single individual. The employment of the shaded segments to represent the various proportions of the three salts is an adaptation of the scheme employed by Harris[5] in his study of alkali salts. The unshaded segments in each circle represents the number of tenths of the total concentration derived from calcium nitrate, the segments marked by small crosses the number of tenths derived from monopotassium phosphate, and the stippled segments the number of tenths due to magnesium sulfate. Proceeding from the base to the apex of the triangle, the rows are numbered from R1 to R8, while the individual cultures in each row are numbered from left to right. For example, the second culture from the left in the first row is designated R1C2, and similarly the third culture in the sixth row is R6C3. Triangle A of figure 23 shows that all of the solutions supplied to the first row of cultures have approximately one tenth of their total concentration from monopotassium phosphate and those in the second row two tenths, this amount increasing by

[5] Harris, F. S. Effect of alkali salts in soils on the germination and growth of crops. *In* U. S. Dept. Agr., Jour. Agr. Research, 5: 12–27. 1915.

increments of one tenth from row to row until the apex is reached. As indicated by the shading, the first culture at the left in each row has one tenth of its total concentration due to calcium nitrate, this partial concentration increasing uniformly by increments of one tenth until the opposite side of the triangle is reached. In a similar

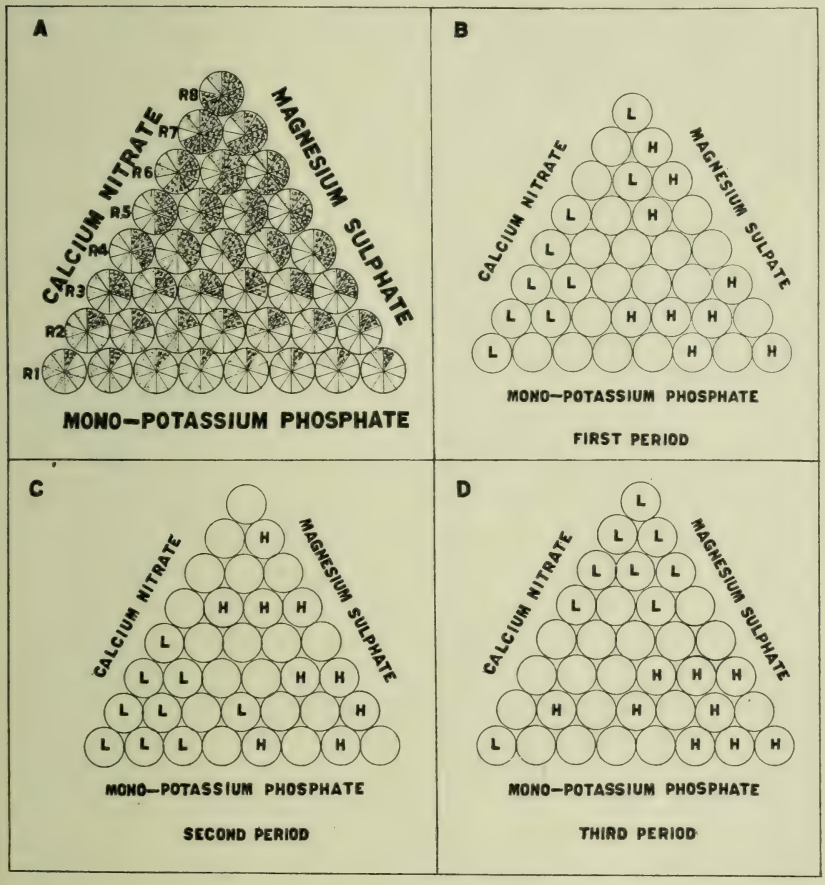


FIG. 23. Triangle *A* shows the salt proportions employed for each culture; and *B*, *C*, and *D* the locations of the best nine and the poorest nine cultures for the first, second, and third growth periods, respectively.

manner the partial concentrations of magnesium sulfate increase from right to left in each row. The circle occupying the position R2C3 has three tenths of its total area unshaded, two tenths marked by crosses and the remaining five tenths stippled, thus indicating that

the solution used for this culture had the proportions of three tenths calcium nitrate, two tenths monopotassium phosphate, and five tenths magnesium sulfate. Throughout the discussion the individual cultures will be designated by the row number and by the position they occupy in the row, using the nomenclature employed by earlier writers.

In order to study better the growth rates, each of the three series of 36 cultures have been divided into three groups, (1) a lower one fourth comprising the 9 cultures giving the lowest yield of tops, (2) an upper one fourth composed of the 9 cultures giving the highest yield, and (3) a medium one half which includes the remaining cultures.

COMPARISON OF THE RESULTS FOR THE THREE GROWTH PERIODS.

An inspection of the triangular diagrams B, C, and D of figure 23 will facilitate a general comparison of the three sets of cultures representing the three growth periods in the life of the wheat plant. In these diagrams the individual cultures are marked with an *L* if they lie in the low-yield group and with an *H* if they are within the high-yield groups. These groups of cultures will be referred to as the poorest nine and the best nine in the discussion which follows.

From triangle B it will be seen that for the early growth period the solutions which gave the highest yield of tops are characterized by a high calcium nitrate content and a low proportion of magnesium sulfate, while the lowest yield of tops is associated with low calcium nitrate and a high proportion of magnesium sulfate. For this period the effect of the monopotassium phosphate appears to have been almost entirely overshadowed by the other two component salts. A comparison of diagram C, representing the results for the second 30-day period, shows a striking similarity in the location of the areas of high and low yielding cultures, from which it would appear that mineral food requirements of the wheat plant during the second growth period were substantially the same as for the first 30-day period.

From an inspection of triangle D it will be seen that for the third and final growth period the solutions which gave the highest yielding plants are characterized by a relatively high concentration of calcium nitrate and a low proportion not only of magnesium sulfate but also of monopotassium phosphate, while the solutions producing low yields are characterized by a high proportion of monopotassium phosphate, without regard to the ratio of the other two salts. These re-

sults suggest a strong possibility that the acidity of the nutrient solution may be largely responsible for the location of the area of low yielding cultures during the final growth period. The acidity of different nutrient solutions with special reference to the hydrogen in concentration is being made the subject of further investigation.

The mean molecular proportions of the three component salts and the ionic ratios for the culture solutions giving the best and the poorest growth of wheat during the different periods are given in Table 1.

TABLE 1.—*The mean molecular proportions of the three component salts and the ionic ratios for the culture solutions giving the best and the poorest growth of wheat during the different periods of development.*

Series and growth rank.	Mean molecular proportions in tenths of total concentration.			Mean cation ratios.		
	KH_2PO_4.	$Ca(NO_3)_2$.	$MgSO_4$.	Mg/Ca.	Mg/K.	Ca/K.
Series 1, first period. Best nine	3.4	4.7	1.9	1.08	1.50	1.98
Series 1, first period. Poorest nine	3.8	2.0	4.2	6.55	2.80	0.49
Series 2, second period Best nine	3.5	4.6	1.9	1.00	1.48	1.70
Series 2, second period Poorest nine	2.7	1.5	5.8	8.33	5.05	0.71
Series 3, third period Best nine	2.0	5.5	2.5	1.32	2.09	2.60
Series 3, third period Poorest nine	6.1	1.8	2.1	2.99	0.52	0.22

Table 1 shows that for the first period the mean molecular proportions of the solutions producing the best nine are 3.4 parts monopotassium phosphate, 4.7 parts calcium nitrate, and 1.9 parts magnesium sulfate, and for the poorest nine, 3.8 parts monopotassium phosphate, 2.0 parts calcium nitrate, and 4.2 parts magnesium sulfate. For the second growth period these proportions remain practically the same, but for the final period the proportions are materially changed, especially for the low yield group. An inspection of ionic ratio values brings out the fact that for the first and second growth periods the culture solutions producing the best growth are characterized by a low ratio of magnesium to calcium, while the solutions giving low yields have a high ratio value of magnesium to calcium. For the final period this wide difference is absent, the ratio of magnesium to calcium having increased slightly for the best nine and decreased very materially for the poorest nine. Attention is also called to the fact that the mean ratio of magnesium to calcium for the best growth for the first and second periods is practically 1 : 1 and for the final period 1 : 1.3. The mean ratio of magnesium to potassium is practically the same for the best nine for the first and second growth periods, and as in the case of the magnesium-calcium ratio, there is

a slight increase for the final period, thus indicating an increase in the physiological requirement for magnesium during the late stages in the development of the wheat plant.

Further discussion of these data is being reserved until the conclusion of similar studies of the mineral food requirements of the soybean plant and of buckwheat, which are now being conducted by the Department of Soils of the Maryland experiment station.

RELATION OF SIZE OF SAMPLE TO KERNEL-PERCENTAGE DETERMINATIONS IN OATS.[1]

R. J. Garber and A. C. Arny.

In carrying out the rotation investigation and the varietal test work at University Farm, the farm crops section of the Minnesota station has occasion each year to make a considerable number of determinations of percentage of kernel in oats (a) of the same variety grown in different rotations and (b) of a number of varieties grown under similar soil conditions. For oat varieties, these data are of interest as a basis for comparing true yielding ability and feeding value. Inasmuch as hulling oats by hand is rather expensive, it is highly desirable to minimize the work so far as is compatible with accuracy. The data collected in seeking a solution to this problem are presented herein.

Love (1912)[2] determined for two crops of oats the bushel weight, the weight per 100 grains, and the percentage of kernel for each of a large number of varieties. The weight per 100 grains was obtained by weighing several composite lots of from 50 to 100 grains and averaging these for each variety. Kernel percentage determinations were made from the weighed samples. Love found a difference of nearly 100 percent in the weight per 100 grains as determined for the different varieties. Comparing the weight per 100 grains within any variety for the 2-year period, the variation was not great. He found a considerable variation in percentage of kernel for the different varieties, but no variety showed a wide variation for the 2-year

[1] Published with the approval of the Director as Paper No. 104 of the Journal Series of the Minnesota Agricultural Experiment Station, St. Paul, Minn. Received for publication December 26, 1917.

[2] Dates in parenthesis refer to "Literature cited," p. 142.

period. No correlation was found between weight per hundred grains and percentage of kernels or between weight per bushel and percentage of kernel.

Surface and Zinn (1916) give data showing no relation between weight of a thousand grains and percentage of hull.

The thirteen varieties studied in this investigation (Table 1) were

TABLE 1.—*Weight of 1,000 grains and mean percentage of kernel in 13 varieties of oats with the standard deviation and coefficient of variability in twenty 50-grain samples of each variety.*

Variety.	Group.	Weight of 1000 grains.	Means.	Standard deviations.	Coefficients of variability.
Swedish Select	Sativa	29.090	72.19±.14	.9500±.10	1.32±.14
Silvermine	do	23.500	71.73±.13	.8599±.09	1.20±.13
Victory	do	25.415	72.56±.18	1.1795±.13	1.63±.17
Banner	do	25.990	71.92±.12	.7901±.08	1.10±.12
Improved Ligowa	do	23.505	72.55±.17	1.1146±.12	1.54±.16
Sixty Day	do	18.645	72.23±.14	.9202±.10	1.27±.14
Iowa No. 103	do	19.525	72.39±.19	1.2851±.14	1.78±.19
White Tartar	Sativa orientalis	26.620	74.05±.10	.6601±.07	.89±.09
Black Tartarian	do	20.410	69.75±.15	.9641±.10	1.38±.15
Storm King	do	45.455	62.16±.18	1.2248±.13	1.97±.21
Garton No. 748	do	21.220	76.70±.12	.7924±.08	1.03±.11
Red Rustproof	Sterilis	33.220	72.80±.11	.7055±.08	.97±.10
Burt	do	24.095	73.26±.13	.8675±.09	1.18±.13

grown on University Farm in 1917 and all but the five last named, which grew on the plots devoted to classification work, appeared in the regular varietal tests. The oats taken from these two sources were thrashed similarly, so their respective percentages of kernel are directly comparable. It was thought advisable to select varieties differing as widely as possible in size and shape of grain, in percentage of kernel, and in other characteristics. By so doing, a range of 62.16 to 76.70 in percentage of kernel was obtained, which was greater than would ordinarily be found in any one variety over a period of years and consequently obviated the necessity of using the crop from more than one year.

The method employed in making the kernel determinations was as follow: A composite sample of a pound or more was made up for each variety by taking portions from various places within the bags containing the bulk oats. These composite samples were taken to the laboratory and each thoroughly mixed. Then, as desired, a composite sample was poured into a conical pile, from one side of which the samples used in determining the kernel percentages were taken. The grains were counted out just as they came and, with the exception of broken or diseased ones, which were rejected, no selection

whatever was made. The twenty 50-kernel samples of each variety were collected at one time and numbered consecutively from 1 to 20. Number rather than weight of grains was chosen as a basis for sampling because the former was more convenient. The average weight of any sample used may readily be ascertained from the weight of 1,000 grains for the same variety, as given in Table 1. Table 2 shows the frequency distributions of kernel percentages in the different varieties.

TABLE 2.—*Frequency distributions of kernel percentages of 13 varieties of oats, as shown by determinations of twenty 50-grain samples of each variety.*

Classes.	Swedish Select.	Silvermine.	Victory.	Banner.	Imp. Ligowo.	Sixty-Day.	Iowa No. 103.	White Tartar.	Black Tartarian.	Storm King.	Garton No. 748.	Red Rustproof.	Burt.
60.25										3			
60.75										1			
61.25										2			
61.75										3			
62.25										2			
62.75										2			
63.25										3			
63.75										3			
64.25										1			
* * *													
67.75									1				
68.25									1				
68.75									2				
69.25							1		3				
69.75		1	1						7				
70.25	1	1		1	2		1		1				
70.75	2	2	1	1	1	2	1		3				
71.25	2	2		4		4	1		1			1	1
71.75	2	7	3	6	3	1	3		1			2	1
72.25	3	5	3	2	1	5	2					3	2
72.75	5	1	6	4	6	5	4	1				5	4
73.25	4		3	2	2		4	3				5	2
73.75	1	1	1		4	3	1	4				4	5
74.25							2	7					5
74.75			1		1			2					
75.25			1					3			2		
75.75											1		
76.25											4		
76.75											5		
77.25											4		
77.75											4		

Double oats, commonly so called where the lemma of the primary grain completely or almost completely envelops the secondary grain, were counted as one. This accounts for the seemingly high weight of 1,000 grains of the Storm King variety.

The weighings of the samples before hulling and of the kernels afterward were made in grams to three decimal places on a Troem-

ner enclosed balance. The kernels were carefully removed by hand.[3] In order to insure more accuracy only one person worked on the seeds of each variety.

After the data were collected and the various kernel percentages calculated, tables of the same form as Table 3, which is presented as a representative one, were prepared for each variety. All the varieties were handled exactly alike, so an explanation of one table will suffice. The column headed "Number of samples" gives the number of frequencies involved in determining the statistical constants for the various replications. Here an explanation in regard to how the replications were made is necessary. As has been stated. the 20 50-kernel samples were numbered from 1 to 20. To secure 1 replication the mean percentages were calculated for samples 1 and 11, 2 and 12, 3 and 13, etc., until the entire 20 were used to make up the resultant 10 mean percentages. For 2 replications, samples 1, 7 and 13; 2, 8 and 14, etc.; for 3 replications, samples 1, 6, 11 and 16; 2, 7, 12 and 17, etc.; for 4 replications, samples 1, 5, 9, 13 and 17, etc.; for 5 replications, samples 1, 4, 7, 10, 13 and 16, etc.; for 9 replications, samples 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19, etc., were similarly combined and the means determined. Each mean so obtained represents one of the percentage frequencies for that particular replication. Thus, where one replication is made, 10 percentage frequencies each representing 100 oat grains result; where two replications are made, 6 percentage frequencies each representing 150 grains result; and so on for the various replications. The first horizontal column of Table 3 gives the constants where single 50-grain samples only were

TABLE 3.—*Variability of percentage of kernel in Swedish Select oats.*

Replications.	No. of kernels in each sample.	No. of samples.	Means.	Standard deviations.	Coefficients of variability.
None.....	50	20	72.19±.14	.9500±.10	1.32±.14
One.....	100	10	72.19±.10	.4805±.07	.67±.10
Two.....	150	6	72.25±.11	.3942±.08	.55±.11
Three.....	200	5	72.19±.09	.2946±.06	.41±.09
Four.....	250	4	72.19±.09	.2800±.07	.39±.09
Five.....	300	3	72.25±.08	.2086±.06	.29±.08
Nine	500	2	72.20±.04	.0852±.03	.12±.04

considered. Table 1 presents this data for the several varieties studied, together with the weight of 1,000 grains of each variety.

Considering the standard deviations as given in Table 3, it is apparent that a 50-grain sample with a constant of .9500 ± .10 gave a

[3] The hulling was done by two student assistants, B. A. Holt and G. R. Kokatnur, and the senior author.

less accurate determination than a 100-grain sample with a constant of $.4805 \pm .07$. The standard deviation of the former is almost double that of the latter. Between 100-grain and 150-grain samples there is much less difference, but still some decrease in the standard deviation. Relatively the same decrease is shown in going from the 150-grain to the 200-grain samples. Increasing the sample to 250 grains gave a standard deviation of $.2800 \pm .07$, which is not a marked reduction. However, the use of 300-grain and 500-grain samples gave standard deviations of $.2086 \pm .06$ and $.0852 \pm .03$ respectively, which are more decided reductions. The difference between this constant, where one replication representing 100-grain samples and nine replications representing 500-grain samples were used, is $.3953 \pm .08$, which is more than four times its probable error and consequently has some statistical significance. The foregoing observations are likewise brought out by considering the coefficients of variability. In general, similar tables worked up for each of the other twelve varieties gave results concordant with those of Table 1, but there was not always the same comparatively uniform diminishment in standard deviations and coefficients of variability. This is well shown in Table 4.

It will be noted from Table 3 that the means of the different replications vary but slightly, the actual difference between the two extremes being but 0.06 percent. This, in general, held true for all the varieties. In most cases the difference between the extremes was less than 0.05 percent and in no instance was it greater than 0.12 percent. Uniformity of the means within each variety establishes a close correspondence between standard deviations and the related coefficients of variability, except that the latter are numerically greater. The relatively high value of the means compared with their absolute differences within any one variety also serve to make the two indices of variation for any one replication closely reciprocal. In view of these facts, Table 4 includes only the coefficients of variability rather than both the coefficients and the standard deviations, which would be largely a duplication.

Table 4 gives all the coefficients of variability for the twenty 50-grain samples and the different replications for each of the thirteen varieties, together with the statistical constants of these coefficients. Consider the column headed single 50-grain samples. Here the coefficients of variability of each of the 50-grain samples is given opposite the variety from which the determination was made. It is interesting to note in this connection that in no case does the coefficient

TABLE 4.—*Coefficients of variability for the twenty 50-grain samples and the different replications for each of the 13 varieties studied, together with the statistical constants of these coefficients.*

Varieties.	Number of replications.						
	Single sample.	One.	Two.	Three.	Four.	Five.	Nine.
Swedish Select	1.32±.14	.67±.10	.55±.11	.41±.09	.39±.09	.29±.08	.12±.04
Silvermine	1.20±.13	.60±.09	.75±.15	.33±.07	.43±.10	.34±.09	.03±.01
Victory	1.63±.17	1.26±.19	.84±.16	.63±.13	.76±.18	.14±.04	.57±.19
Banner	1.10±.12	.77±.12	.68±.13	.27±.06	.41±.10	.55±.15	.05±.02
Improved Ligowa	1.54±.16	1.05±.16	.49±.10	.68±.15	.38±.09	.13±.04	.36±.12
Sixty Day	1.27±.14	.79±.12	.72±.14	.57±.12	.48±.11	.14±.04	.08±.03
Iowa 103	1.78±.19	1.25±.19	.72±.14	.69±.15	.85±.20	.62±.17	.30±.10
White Tartar	.89±.09	.57±.09	.63±.12	.44±.09	.13±.03	.22±.06	.13±.04
Black Tartarian	1.38±.15	.46±.07	.65±.13	.29±.06	.79±.19	.43±.12	.30±.10
Storm King	1.97±.21	1.17±.18	.90±.18	.78±.17	.76±.19	.55±.15	.31±.10
Garton 748	1.03±.11	.47±.07	.49±.10	.38±.08	.21±.05	.43±.12	.18±.06
Red Rustproof	.97±.10	.58±.09	.54±.11	.33±.07	.37±.09	.19±.05	.21±.07
Burt	1.18±.13	.84±.13	.71±.14	.71±.15	.39±.09	.75±.21	.05±.02
Statistical constants of the coefficients of variability for the 13 varieties.							
Means	1.33±.06	.81±.05	.67±.02	.50±.03	.49±.04	.37±.04	.21±.03
Standard deviations	.3111±.04	.2771±.04	.1217±.02	.1741±.02	.2202±.03	.1970±.03	.1503±.02
Mean coefficient of variability	23.39±3.26	34.21±5.03	18.15±2.48	34.82±5.13	44.94±7.04	53.24±8.82	71.57±13.47

exceed 2 percent. The mean of the coefficients appears near the bottom of the column. The standard deviation and the coefficient of variability immediately following were obtained in the usual way. In other words, each set of statistical constants near the bottom of Table 4 was computed from thirteen variants each of which is an index of variation for a definite number of samples composed of a definite number of grains.

Considering the table from the standpoint of varieties, it is found that they differ widely in degree of variability. For instance, the variety of Storm King, with its comparatively high percentage of hull, has a coefficient of variability of $1.97 \pm .21$, which is about twice as much as that for Red Rustproof, $.97 \pm .10$. This relationship is maintained fairly consistently throughout the various replications. By comparing these two extremes, it becomes evident that to secure the same accuracy in determining the percentage of kernel, Storm King requires a larger sample than Red Rustproof. Some varieties, as Black Tartarian, show considerable fluctuation and lack of consistency for the various replications. This undoubtedly is due to the somewhat small number of variants involved. In general, however, the varieties tend to corroborate each other.

Comparing the coefficients of variability in the first and second columns, it is shown at a glance that one replication representing 100-grain samples give much less variability than single 50-grain samples. In nine out of thirteen cases the coefficients for one replication is greater than for two replications, as is shown by comparing columns two and three. Two replications except in two instances give higher coefficients than three replications. Between 200-grain and 250-grain samples represented by 3 and 4 replications, respectively, there is little difference in the coefficients. On the average, 500 grains constitute a somewhat more representative sample for the determination of percentage of kernel than 300 grains.

Examine next the statistical constants of the coefficients of variability. The mean of each column is not presented as an expression of variability for the thirteen varieties considered as one group of variates, but rather as the average of the coefficients of variability for the thirteen varieties, each of which constitutes a group of variates. The highest mean is found for the single 50-grain samples and the lowest for the 500-grain samples. The former also has the highest standard deviation, but the latter has the highest coefficient of variability. Where two replications are made, the standard deviation of the coefficients, $.1217 \pm .02$, is the lowest. In comparing the means of the coefficients for columns 1 and 2, again a decided advantage is

found in favor of using one replication rather than single 50-grain samples. While the mean of the coefficients in column 3, .67 ± .02, is somewhat lower than that of column 2, .81 ± .05, the difference, .14 ± .05, is not quite three times its probable error. The difference between the means of the coefficients in columns three and four is .17 ± .04. Three replications or 200-grain samples diminish the mean of the coefficients for one replication or 100-grain samples by .31 ± .06, which is five times its probable error and therefore significant. The comparatively low variability of the 200-grain samples is another point in their favor. The difference between the means, .01 ± .05, of three and four replications certainly has no statistical value. The differences between the means of four and five replications and of five and nine replications are .12 ± .06 and .16 ± .05, which are two and slightly more than three times their respective probable errors. Between the means of the coefficients of single 50-grain samples and three replications the difference is .83 ± .07, while between the three and nine replications the difference is only .29 ± .04. In other words, 150 grains added to a 50-grain sample reduces the average variability almost three times as much as 300 grains added to a 200-grain sample. Although it is evident from the above data that the 500-grain sample is the most accurate, it is for the individual to determine whether for his purpose it is sufficiently more accurate than the 200-grain sample to justify the additional work incidental to hulling the larger quantity of oats.

In order to examine still further what constituted a desirable sample of oats for determining the percentage of kernel, 100 samples of 50 grains each of Improved Ligowa, which is of a Swedsih Select type, were counted out, the kernel percentage determinations made, and the replications followed in the same systematic way as in the several varieties. The results are tabulated in Table 5. The fre-

TABLE 5.—*Variability in percentage of kernel of Ligowa oats.*

Replications.	No. of kernels in each sample.	No. of samples.	Means.	Standard deviations.	Coefficients of variability.
None	50	100	72.71 ± .07	1.0638 ± .05	1.46 ± .07
One	100	50	72.71 ± .08	.7915 ± .05	1.09 ± .07
Two	150	33	72.70 ± .06	.5161 ± .04	.71 ± .06
Three	200	25	72.71 ± .07	.5430 ± .05	.75 ± .07
Four	250	20	72.71 ± .08	.5113 ± .05	.70 ± .07
Five	300	16	72.68 ± .06	.3545 ± .04	.49 ± .06
Nine	500	10	72.71 ± .08	.3774 ± .06	.52 ± .08

quency distribution of these 100 samples was as follows: 70.25, 5; 70.75, 5.; 71.25, 2; 71.75, 15; 72.25, 9; 72.75, 18; 73.25, 18; 73.75, 19; 74.25, 7; and 74.75, 2.

One replication reduces the coefficient of variability of single 50-grain samples by $.37 \pm .10$ and two replications further reduce the coefficient by $.38 \pm .09$, thus making a difference between 50-grain and 150-grain samples of $.75 \pm .09$, which is approximately eight times its probable error and, therefore, of statistical value. Considering replications two, three, and four, no difference of statistical significance appears; likewise, between five and nine replications. The difference between four and five replications is only $.21 \pm .10$, while between five and nine replications, it is negligible.

In view of the foregoing facts a 150-grain sample of Improved Ligowa oats taken as described gave as statistically representative a sample as a 200-grain or a 500-grain sample. These results with the large number of grains of a single variety are in substantial agreement with the interpretation of the data as given for the thirteen varieties.

Conclusions.

From the data presented in this study, the following conclusions may be drawn:

1. In general, a 200-grain sample taken as has been described gives a sufficiently accurate determination of percentage of kernel in oats for all ordinary purposes. The weight of this size of sample varies from 3 grams in early to 5 grams in midseason and late varieties in Minnesota.

2. Where more than ordinary accuracy is necessary, the sample should be increased to at least 300 grains, and with some varieties still larger samples are desirable.

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1912. Oats for New York. N. Y. Cornell Univ. Agr. Expt. Sta. Bul. 343, p. 407–416.

Surface, Frank M., and Zinn, Jacob.
1916. Studies on oats breeding. Maine Agr. Exp. Sta. Bul. 250, p. 140–141.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the January issue was 656. Since that time 16 new members have been added, 3 have resigned, 1 has died, and 30 have lapsed for nonpayment of dues of 1916, a net loss of 18 and a present membership of 638. The names and addresses of the new members, names of those lapsed, deceased, and resigned, and such changes of address as have been noted since the last issue, are as follows:

New Members.

Anderson, Arthur, Univ. Farm, Dept. of Agronomy, Lincoln, Neb.
Barbee, O. E., Cliff House, Pullman, Wash.
Berry, Roger E., 404 Knoblock St., Stillwater, Okla.
Gordon, Thomas B., Mass. Agric. College, Amherst, Mass.
Haseltine, L. E., 2301 Durant Ave., Berkeley, Calif.
Hatcher, Otto, 318 West St., Stillwater, Okla.
Hildebrand, E. B., 112 N. Main St., Stillwater, Okla.
Johnson, D. R., 220 Knoblock St., Stillwater, Okla.
Johnson, George F., 256 W. Woodruff Ave., Columbus, O.
Kearney, T. H., Bureau of Plant Industry, Washington, D. C.
McDowell, C. H., Supt. Substation No. 6, Denton, Texas.
McGuffey, C. Carl, McGuffey, Ohio.
Thompson, R. S., Highland, Calif.
Turner, A. F., K. S. A. C., Manhattan, Kans.
Wells, W. G., Bur. Plant Ind., U. S. D. A., Washington, D. C.
Wunsch, W. A., Acting Co. Agt., Newton, Kans.
Zinn, Jacob, Agric. Experiment Station, Orono, Me.

Members Resigned.

Edwards, R. W., Kyle, C. H., Worthen, E. L.

Members Lapsed.

L. J. Briggs.
I. N. Chapman.
Ernest W. Curtis.
N. C. Donaldson.
F. V. Emerson.
Raymond C. Gauch.
E. W. Hall.
J. D. Harper.
S. H. Hastings.
D. S. Jennings.
Grover Kinzy.
W. A. Lintner.
R. E. Lofinck.
Jas. McAdams.
G. W. Morgan.
D. S. Myer.
A. J. Ogaard.
W. M. Osborn.
A. W. Palm.
J. W. Paxman.
Martin Reinholt.
R. R. Reppert.
A. M. Richardson.
J. C. Robert.
C. H. Ruzicka.
E. B. Watson.
Isaac Weisbeim
W. A. Wheeler.
Casper A. Wood.
Harry P. Young.

MEMBERS DECEASED.

MALON YODER.

CHANGE OF ADDRESS.

P. V. CARDON, Experiment Farm, Moccasin, Montana.
FOERSTERLING, H., care The Arbor Farm, Jamesburg, N. J.
FOORD, J. A., 54 Lincoln Ave., Amherst, Mass.
JENSEN, L. N., Box 1214, Amarillo, Texas.
MACKIE, W. W., 121 Hilgard Hall, Berkeley, Cal.
WESTOVER, H. L., Bard, California.
WHEELER, H. C., Agric. Bldg., Urbana, Ill.
WOODARD, JOHN, 381 Paisley Road, Guelph, Ont., Canada.

NOTES AND NEWS.

A. R. Mann, who has been acting dean of the college of agriculture and director of the experiment station of Cornell University, has been made dean and director.

Walter Packard, formerly in charge of the Imperial Valley Experiment Farm at El Centro, Cal., is now chief of farm advisors for the southern half of California, with headquarters at Berkeley.

J. T. Parsons has been appointed soil technologist and O. I. Snapp has been made assistant in soils at the Ohio station.

Gordon W. Randlett, for the past two years director of extension in South Dakota, has been elected to a similar position in North Dakota.

Bernard F. Sheehan, formerly of the Iowa station, has been appointed instructor in farm crops at the Oregon college and station.

L. Van Es, for many years veterinarian of the North Dakota Station, has been elected director of that station.

C. W. Warburten, a member of the Committee on Seed Stocks of the U. S. Department of Agriculture, is now engaged in the purchase of seed grain for resale to farmers at cost in the sections of North Dakota and Montana where crops failed last year. This work is under the provisions of the emergency food production bill. Mr. Warburton's headquarters are in Minneapolis while engaged on this work.

W. R. Ward, instructor in agronomy, and Horace J. Young, assistant professor of agronomy, both of the University of Nebraska, are emergency district demonstration leaders in that state.

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METHODS USED AND RESULTS OBTAINED IN CEREAL INVESTIGATIONS AT THE CORNELL STATION.[1]

H. H. LOVE AND W. T. CRAIG.

INTRODUCTION.

During the past few years considerable interest has been manifested in the methods used in the various experiments of crop research, and considerable change in the handling of experiments in all agronomic investigations has resulted. This has been especially true with regard to the small grains. When, in addition to testing a few of the better-known varieties, selection and breeding work was undertaken, it was important to be able to handle a large number of sorts. This demanded a change in methods so that fair comparative results could be obtained without unnecessarily large acreage being devoted to any certain crop. The tendency has been to reduce the size of plat more and more until finally in a number of places the rod-row system has been adopted. So far as is known to the authors Mr. J. B. Norton, of the United States Department of Agriculture, was the first to put this method in general use.

Montgomery[2] has discussed this method in relation to plat trials. Since the authors in their work at the Cornell University Agricultural Experiment Station[3] have for a number of years been using

[1] Paper No. 64, Department of Plant Breeding, Cornell University, Ithaca, New York. Presented by the senior author, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Montgomery, E. G. Experiments in wheat breeding; experimental error in the nursery and variation in nitrogen and yield. U. S. Dept. Agr., Bur. Plant Indus. Bul. 269, 1913.

[3] This work is in cooperation with the Bureau of Plant Industry, United States Department of Agriculture.

this method rather extensively in connection with cereal breeding work it seems worth while to present some description regarding its details. In addition, the methods used in selection and hybridization will be discussed, with a brief statement of the results obtained.

Methods Used in Making and Testing Selections.

Two methods are used in making selections with which to begin comparative trials. The first is to travel through the State making selections from various fields. In making these selections the different types present in the field are collected, as well as the main type represented. Care is taken to select from that part of the field which represents average conditions as nearly as can be ascertained. Heads are selected rather than plants, owing to the difficulty of separating individual plants with certainty. In this sort of selection it is important to make collections from as many different fields as possible and to cover a wide area, so that various growth conditions may be encountered.

The second method followed is to make plantings of a selected variety or varieties from which selections are to be made. Individual kernels are planted 1 foot apart each way in ground previously prepared and marked off. In this way it is possible to study the entire plant and make comparisons as to stooling habits, stiffness of straw, and the like. An objection to this method is that it is not possible to make selections on such a large scale as when they are made from the field. That is, from the field the selections represent the best from a vast number while from the hill method they represent the best from only several thousand at most. This objection is partly offset by the fact that a more detailed study can be made of the individuals selected and that a larger quantity of seed is obtained than is possible from a single head. In either case it is very important to start with a very large number of heads or plants.

After these heads are selected they are then thrashed and prepared for planting. Few notes are taken on the heads as the more detailed study of the new sorts is made later on in the trials. For thrashing these heads a small head-thrasher has been constructed by Mr. H. W. Teeter, of the Department of Plant Breeding. No screen or fan is attached to this machine, as it is used also for a great amount of statistical work where all kernels, even the light ones, are to be saved. A small electric motor furnishes the power. Very rapid work can be done with this machine, which is operated by one man. A hundred or more heads can be thrashed and cleaned per hour.

When heads are selected the seed is sown in head rows the first year. In order to have a uniform seeding the seeds are counted out so that the same number may be sown in each row. The seeds are placed in an envelope and this envelope numbered with the proper row number. Sometimes it is necessary to sow in two lots, as it is not always possible to obtain the same number of seeds from each of the heads chosen. For example, it may be necessary to plant a series where 30 seeds per row and another where 25 seeds per row are used.

For wheat these head-rows are now 2.5 feet long and for oats 5 feet long. Usually 25 or 30 seeds are used in each head row for wheat and 40 to 60 for oats. As stated above, the number of seeds used depends on conditions affecting the size of head selected.

These seeds are scattered in the drills thinly and are not spaced, as experience has shown that for such work careful spacing is not necessary. It is more important to have a very large number of selections under test and depend on them to furnish something worth while than to handle a few selections with greater attention to detail. For example, this year we have under test 2,200 new selections of wheat and two years ago we had 1,600. It is our plan to start a new selection series every two years. This works out to better advantage than starting a series every year, as it gives time for the elimination of the poorer sorts. The number of head rows of wheat that can be sown in a day by five men is about 2,000 to 2,500, while for oats it is less, as the row is longer and more seeds are to be dropped.

If plants rather than heads have been used as a basis for selection then more seed is available and a definite quantity of seed may be weighed out for each plant row. Weighing may be objected to since the number of seeds from a large-seeded sort will be less than from a small-seeded one. It has been shown, however, that within a rather wide range the difference in number of seeds will not affect the final results. With plants it will be possible also to have longer rows than with heads.

It may be worth while to mention how these drill rows are prepared for sowing. The land to be used is put in as good tilth as possible. Then a sled marker with runners a foot apart is used to mark off the field. This is then followed with a single-shovel plow to open the drills. When the ground is in good condition a little Planet, Jr., plow with disk attachment is used for covering; otherwise, hoes are used. The marker and drill are started a little while before sowing, marking and opening the drills across the plat of

ground to be used. This makes for more rapid work, as the rows are all laid out before any stakes or lines are placed. The rows and paths between the series can then be measured off and lines run to mark the end limits for a large number of rows at once. This plan is used whether head or rod rows are to be sown.

While the plants in the head rows are growing and developing general notes are taken which with the yield of grain help to determine the worth of a particular selection. At harvest time the rows are studied, usually by two persons, and those rows that are apparently superior are harvested and tagged. No selection of plants from these rows is made, as it is not possible to change the type by reselecting plants from these rows which, barring accidental crossing, are already pure lines. Some natural crossing occurs with wheat; these hybrid rows are usually discarded. No natural oat hybrid has yet been found. A large number of the head rows are left in the field because they show clearly that they are not worth continuing. It may be argued that one year's test is not sufficient to determine the value of a selection. This may be partially true, yet if these selections have been made from varieties adapted to the locality it would be expected that the better selections would show up well the first year. Then, too, the selection of these head rows is not made so closely but that practically all of the better ones are retained. About three fourths of the rows are usually discarded the first year. We feel that by discarding in this manner and bringing in new selections every second year as indicated greater progress will be made than by keeping a large number of strains of doubtful value.

These head rows are then thrashed and the grain weighed and recleaned for sowing the second year. After thrashing a few of the poorest may be discarded, although as a rule those that have passed the field inspection are retained for at least one more year. These selections are sown in triplicate rod rows the second year provided there is enough seed; if not, they are sown in duplicate rod rows.

The amount of seed to be sown per row is calculated from the usual rate of seeding for any particular grain. The seed is weighed and put into envelopes and the envelopes numbered with the proper row number according to the plan of planting. After all of the envelopes are numbered these numbers are checked with the plan of planting to be sure all are in their proper order. A check row is sown every tenth row. Seed for this check is taken from a standard sort or an improved strain. The check rows are marked with numbered stakes which serve as an aid in taking notes and harvesting.

In this way any variations in soil differences may be determined. The seed is sown by hand from the envelopes and it is possible for five men to sow 1,000 to 1,200 rows a day. It is found that with a little experience in sowing the seed can be distributed just as evenly as with a drill.

The plan of planting is arranged so that no two rows sown from the same sort come together. For example, if there are 144 sorts to be tested these together with the check rows will make 160 rows. This series of 160 rows is sown and the series is then repeated; that is, row 161 is the same as row 1, 162 the same as 2, and so on for the entire series. In order to prevent any effect which may be caused by two unlike sorts growing together the different strains are arranged according to earliness and other characters so as to reduce this source of error to a minimum. Some of the rod rows of wheat are shown in Plate 4, figure 1.

The length of these so-called rod rows varies, depending on the kind of crop being handled. All of the weights of grain are taken in grams and the yields per row estimated in bushels per acre. In order to make these calculations as simple as possible the length of the row is so changed that some simple factor is used to convert grams per row into bushels per acre. The oat rows are 15 feet long and the grams per row are multiplied by 0.2 to obtain bushels per acre. For wheat the length is 16 feet and for barley 20 feet, the conversion factor in each case being 0.1.[4]

In every case it is desirable to sow longer rows than are harvested. With oats and barley these rows are sown 1 foot longer, or 16 and 21 feet, respectively. For wheat, which must stand through the winter, the row is 2 feet longer or 18 feet. It is obvious that if the end of each row is cut off, more nearly uniform conditions may be obtained and the effect of increased nutrition which occurs at the ends will not enter into the calculations and modify the results.

During the growing season any desired notes are taken on the rows, such as disease resistance, height, habit of growth, type of head, and the like. At harvest time the rows are cut and carefully tagged and bound. The bundles are bound near the butt with twine, while wired Denison tags which have been previously numbered in accordance with the plan of planting are used to tie the bundle near the heads. When harvesting rod rows it is better to have three men in a team, two to cut and one to tie and label the bundles. A pole

[4] These factors are in reality 0.200066 + and 0.100033 +, but the remainder of the fraction is so small that it does not affect the result when only the first significant number is used in each case.

of the proper length is used to cut the rows by so that the exact length is harvested. Three men will cut from 300 to 400 rows a day. The bundles are not bagged to prevent mixing but are taken immediately into the thrashing shed and hung heads down in the same order that they are grown in the field. This method of hanging (Plate 4, fig. 2) was designed by the junior author and is so planned that ten bundles can hang in a row. These are hung on nails driven into strips. The system is flexible so that the different quantities of straw can be accommodated. These strips rest on supports which are hung from the roof of the building. These supports are 2×6 inches and one of them is notched at various distances so that the strips may be held in an upright position. These notches make it possible to shift the strips in accordance with the quantities of straw and size of the bundle. This system allows the grain to dry thoroughly without mixing and keeps it in good condition until thrashing. When the grain is cared for in this manner the thrashing of oats and barley may be left until the wheat is thrashed and sown again and the other summer work finished.

At thrashing time the three bundles of each sort are gotten out, which is easily done by the system of hanging. These bundles are thrashed individually, but it is not necessary to clean the machine thoroughly after every row as would be the case if the bundles were taken out of a pile just as they came. It is only necessary to clean the machine thoroughly after each variety, thus facilitating thrashing. Before thrashing the total weight of straw and grain is taken and after the grain is thrashed and weighed the yield of straw may be obtained by taking the difference between total weight and weight of grain.

The thrashing of these rod rows is done by means of a specially constructed machine designed by Mr. H. W. Teeter, of the Department of Plant Breeding. This machine is so built that the screens are in sight and after finishing with one sort if any grain remains behind it can be seen and brushed out. The thrashing can best be done by four men. One man can follow the plan of planting and get out the bundles, one do the feeding, one bag and label the grain, and the fourth can look after the machine and take care of the straw. It is possible to thrash about 500 to 600 rows of wheat and 450 to 550 rows of oats in a day.

As the different rows of each sort are thrashed at the same time they can be kept together and the work thus simplified. After the individual weights of row are obtained the grain from the several

FIG. 1. View of rod rows of wheat at the Cornell Station.

FIG. 2. Method of hanging bundles from rod rows.

rows is brought together, weight per bushel tests are obtained, and the seed prepared for sowing another year. These weights per bushel are taken by means of an apparatus described in a previous article,[5] which gives very accurate results. The variation between different determinations of the same variety is very small. This apparatus is similar in operation to one described more recently by E. G. Boerner.[6]

The selections for further testing are then made, basing them on yield and other qualifications. In the third year of this test those sorts that are continued in the rod-row series are repeated ten times, with a check every tenth row the same as the second year (Plate 4, fig. 1). The method of handling, so far as sowing, measuring the rows, and the like are concerned, is the same as has been described.

At thrashing time the ten bundles of a sort are brought together. These are thrashed by individual rows in order to have the data to study the variation of the same sort in different parts of the field. If such data are not desired then it is possible to thrash all ten bundles together, letting the total weight represent the yield of the sort under the conditions tested. This eliminates a great deal of the detail work of thrashing, thus making it possible to thrash about 30 sorts of 10 rows each per hour.

The different strains are continued in the rod-row series for at least three years before any one is eliminated unless it is evident that a particular strain is not at all adapted to the given locality. In addition to the rod-row series a few of the better selections which give evidence of superior merit are grown in increase plats. These increase plats vary in size from year to year, depending on the number of sorts to be grown and the land available. They are so planned, however, that they may be run in duplicate or triplicate and therefore be of use as variety tests.

Any new sorts which have given good yields for a number of years are then tested further by sending seed to farmers who are willing to cooperate to the extent of making comparative trials of the new sort with the varieties grown in their locality.

The value of the rod-row system has been much discussed and various objections have been made to its use. The tendency now, however, is to give this method its rightful place in agronomic technic.

[5] Love, H. H. Methods of determining weight per bushel. *In* Jour. Amer. Soc. Agron., 7: 121–128. 1915.

[6] Boerner, E. G. Improved apparatus for determining the test weight of grain, with a standard method of making the test. U. S. Dept. Agr. Bul. 472. 1916.

To those who have given careful thought and study to plat methods it is evident that by using a rod-row system and replicating a sufficient number of times the probable error of the average yield is reduced to a very low degree. This is illustrated by some data presented here which are taken from some of the rod-row records.

Wood and Stratton[7] have said regarding the use of small plats that for very small plats of one-one thousandth to one-five thousandth of an acre the probable error may be reduced by replicating the plats systematically. They predicted that the probable error of one such plat could be reduced to about 12 percent and that for nine such plats to about 4 percent..

The rod-row plats are about half way between the two sizes of plat mentioned. It is of interest then to present some data on the yields of rod rows repeated ten times. These yields, with the means and probable errors, are given in Table 1 for some varieties of wheat and oats.

TABLE 1.—*The average yield and probable errors and probable error as percentage of the mean of some varieties of wheat and oats tested by the rod-row method.*

Variety.	Mean and probable error.	Probable error as percentage of the mean.
WHEAT.		
Jones Longberry	44.70 ± 1.42	3.18
Dawson Golden Chaff 522–68	42.09 ± 1.00	2.38
Gypsy	41.88 ± 1.23	2.94
Gold Coin	39.11 ± 1.06	2.71
Harvest King	39.04 ± 1.46	3.74
Rural New Yorker No. 57	37.94 ± .97	2.56
Fishhead	37.17 ± .48	1.29
Average		2.69
OATS.		
Welcome selection 123–5	80.40 ± 2.90	3.61
Silvermine	76.64 ± 2.33	2.90
Silvermine selection 120–9	75.20 ± 2.19	2.91
Sixty Day 5938–1	73.60 ± 1.22	1.66
Lincoln	72.28 ± 2.36	3.27
Heavyweight	72.18 ± 2.60	3.60
Burt × Sixty Day	59.52 ± 2.32	3.90
Average		3.12

These are only a few of the many tests, yet as the varieties were selected at random they fairly represent the average condition for

[7] Wood, T. B., and Stratton, F. J. M. The interpretation of experimental results. *In* Jour. Agr. Sci., vol 3, part 4. 1910.

wheat and oats. It is seen that the probable error of the mean, expressed in percentage, varies between 1.29 and 3.74 for wheat and between 1.66 and 3.90 for oats. The average of the probable errors expressed in percentage is 2.69 for wheat and 3.12 for oats, which is well within the limits predicted for such work by Wood and Stratton.

The relation between the rod-row yield and plat yield for a few varieties grown the same year has been plotted graphically (fig. 24) in order to show the relation between the yields of the same strains tested under the different conditions. The broken line represents the yield of the rod rows of wheat for 1916, while the solid line represents the yield of the same strains tested on one two-hundredth-acre plats repeated three times. The yields do not follow in exact order but in general the relationship holds. This is well illustrated by means of the straight line fitted to the plat yields. The equation to this line is $y = 37.253 + .177x$. When one considers the fact that for the rod rows and drill plats it is very difficult to have all conditions similar the variation between the two methods is not unexpected. The relation between the yields of the two methods is practically the same as the data published by Montgomery show.

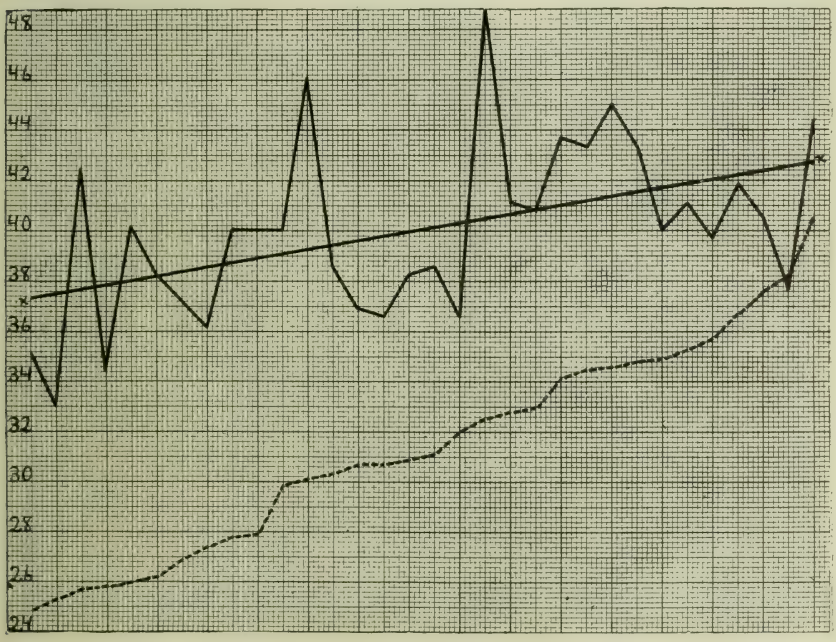

FIG. 24. Graph showing relation of yield of wheat varieties in 1916 when same sorts were grown in rod rows repeated ten times and in two-hundredth-acre plats repeated three times.

This chart also shows a marked difference between the yields of the rod rows and the plat yields. The plat yields are with one exception considerably higher than the row yields. The average for all the plats is 40 bushels per acre, while for the rows of the same varieties it is 31.4 bushels. This overcomes the objection often made against the rod-row system that the yields are higher than plat trials. To be sure, there is some difference in stand under the two systems.

As the probable error is reduced so low with rod rows one seems justified in using this method, as so many more sorts may be handled on a given area. For example, with oats when the rod rows are repeated ten times they comprise altogether about one two-hundred-ninetieth of an acre which, together with the required paths between the series, makes it possible to handle about 242 sorts repeated ten times on an acre. On the other hand, with two-hundredth-acre plats repeated three times and with 2-foot borders between, it is possible to handle only about 37 sorts. With these facts in mind we feel that for our purpose the rod-row method is the best.

TABLE 2.—*Three-year average yields in bushels per acre of oat and wheat varieties and selections, with the increases obtained.*

OATS.

Variety and selection numbers.	3-year average yield per acre. *Bushels.*	Gain. *Bushels.*
Canada Cluster	56.9	
Canada Cluster 110–36	65.6	8.7
Lincoln	53.2	
Lincoln 109–14	57.4	4.2
Lincoln 109–15	58.4	5.2
Big Four	52.4	
Big Four 115–27	58.3	5.9
Big Four 115–40	57.9	5.5
Clydesdale	50.2	
Clydesdale 114–2	56.7	6.5
Clydesdale 114–4	57.1	6.9
Clydesdale 114–14	57.8	7.6
Clydesdale 114–16	58.0	7.8

WHEAT.

Klondyke	28.2	
Klondyke 126–26	30.4	2.2
Klondyke 126–44	31.3	3.1
Fulcaster	26.0	
Fulcaster 123–23	27.9	1.9
Fulcaster 123–32 (beardless)	30.2	4.2
Red Wave	27.7	
Red Wave 128–47	31.1	3.4

Some of the results obtained by this method of selection and testing are shown in Table 2.

It may be well to summarize the methods used in making selections. The heads or plants are selected and tested for one year in head or plant rows. The best rows are selected in the field, harvested, thrashed and grown the second year in rod rows repeated two or three times, depending on the amount of seed available. Only the very poorest are eliminated the second year. The rest are continued in rod rows repeated ten times for at least three years. The best new strains are multiplied and tested in increase plats. The best ones are finally distributed to farmers for further comparison. In this way a sort is tested for at least six years before it is finally put into general use.

Methods Used in Making and Studying Hybrids.

In making hybrids of the small grains it has been found best to grow the plants to be used for hybridization in pots in the greenhouse. Experience has shown that in most seasons when the plants are grown in the field the hot sun dries up a large number of the flowers which have been emasculated, thus greatly interfering with the work. Another point in favor of growing greenhouse plants is that pollen is available for more hours per day and that the pots can be moved about, thus bringing those being worked close together. The plants, especially in the northern States, develop more slowly in the greenhouse, thus giving more time to complete the work. Another very important point is that the work may be done in the late winter or early spring before the heavy field work of summer comes. Loss from injury by storms is also avoided.

In crossing oats several spikelets on a head are chosen at a time when the anthers are still young and are green in appearance. The smaller or upper flower (or flowers) is removed from each spikelet and the anthers removed from the remaining flowers by means of a small pair of forceps. The spikelets are then tagged with a tag which shows the date of emasculation. After a day or two the flowers are pollinated. This is done usually by collecting anthers that are just ready to burst, placing one in the flower, and carefully replacing the palea. Sometimes when plenty of pollen can be obtained the pistils are dusted with pollen. At other times anthers which are nearly ripe are taken from the plants used for male parents and dropped into the flowers at the time of emasculation. All these methods have given very good results.

In all cases a record is kept showing which particular plant of a variety was used as a male parent. When the hybrid seeds are ripe they are collected, as are also seeds from both the male and the female parents. These seeds are sown in pots again in the greenhouse. Greater care can be given them there than in the field and there is a greater possibility of saving all the plants. Seeds from each of the parents are also grown in order to make direct comparisons between the F_1 plant and the parent types. The seeds from the F_1 plants as well as the parents are saved and the various characters described and noted.

The F_2 and succeeding generations are grown in the field in 5-foot rows. The rows are prepared in the same manner as for the rod rows. In sowing, the kernels are spaced 2 to 3 inches apart in the row. This spacing is not made by exact measurement, as that is unnecessary. One row of each of the parents is also sown for comparison. The 5-foot rows with a 2-foot border between the sections permit the taking of notes on the plants without interfering with their growth. It is also possible to sow more rapidly, as it is possible to guage the spaces needed by the number of seeds in hand. A row may be confined to a single sort, while if longer rows are used it is necessary sometimes to have more than one sort in a row, which leads to confusion and possibly to errors.

At harvest time the plants are pulled if it seems necessary to save seed from a large number. When this is not needed the plants are pulled and a culm cut from each for further study. By saving only a culm it is possible to store a large number of families in a small space. When this latter method is used all of the heads from a fairly large number of different types are saved in large envelopes. In this way seed is retained for the next planting. Unless one saves a rather large number it may be found that not all the types desired are present. In certain wild oat crosses it is necessary to use envelopes for many of the plants to prevent loss by shattering.

When wheat is to be crossed some of the spikelets are removed near the middle of the head, and either the upper or lower flowers emasculated. All but the outside flowers of the spikelet are removed. In some cases the tips of the glumes are cut off and the anthers removed, while at other times the anthers may be removed without clipping the glumes. The heads are then covered with glassine bags made for the purpose. Either way of preparing the head is satisfactory, as the data in Table 3 show:

TABLE 3.—*Results of two methods of emasculation for wheat pollination.*

Number of heads worked	90
Number of heads setting seed	67
Percentage of heads setting seed	74.44
Percentage of heads setting seed when glumes were clipped	74.35
Percentage of heads setting seed when glumes were not clipped	74.51
Average number of seed set	7.2
Average number of seed set when clipped	8.5
Average number of seed set when not clipped	6.2

From these data it is seen that there is practically no difference as to results whether the glumes are clipped or not. This method may be objected to because pollen from the non-emasculated flowers of the head may adhere to the glassine bags so that when they are removed for pollination some of it may fall on the emasculated flowers. Experience does not seem to give this objection any weight. Wheat hybrids in general are handled in the same way.

Most of the notes on these hybrids are taken in the laboratory rather than in the field, though certain notes which can be more readily taken in the field are secured. It is difficult to handle as large a number as we now have and take many notes in the field, particularly as the various sorts soon begin to weather badly and therefore are much discolored. Again, certain crosses of *Avena* species shatter badly unless the plants are harvested rather early.

In addition to the studies in inheritance, any hybrids that give promise of commercial value after becoming fixed as to their characters are placed in the rod-row series for testing.

Space does not permit a full account of the results obtained, yet it is well to mention a few. With oats, color studies have been made in various crosses. In *Avena fatua* × *A. sativa* (variety Sixty-Day) crosses it is found that the yellow color of the Sixty-Day apparently inhibits awn production as well as the production of pubescence. In a cross between two black oats classed as the same type, non-black oats appear in the second generation in the ratio of 15 black to 1 non-black. Crosses between hulled and naked oats show that these characters behave as a simple monohybrid, but that there is apparently some modifying factor present which affects the amount of hull in the heterozygous forms.

With wheat the red color of kernel is found to be represented by one, two, and three factors in inheritance. This is in accordance with the results of other workers. Many crosses between the different species are being studied. Two fertile wheat-rye hybrids have been found, one of which has been carried to the fourth generation.

A SIMPLE METHOD OF DEMONSTRATING THE ACTION OF LIME IN SOILS.[1]

PAUL EMERSON.

Every demonstrator or lecturer realizes the fact that the more vividly he paints his word pictures the more lasting is the impression made on his audience. If the lecture is illustrated it is better understood, even with a poor lecturer, than if not, and the closer the illustrations are to the point the better.

While demonstrating methods for testing soils and determining their lime requirements at a large State fair recently, the writer was asked this very pointed question: "How can you prove to me that limestone has a beneficial action in the soil by neutralizing the acidity?"

The questioner was of the type that demands to be shown rather than told, and his question was answered in the following manner. A few drops of sodium alazarin sulfonate (alazarin red) indicator was put into about 100 c.c. neutral water in a flask. The farmer was asked to note the resulting brown color and also any other change of color that might subsequently appear. Approximately 2 grams of ground limestone were then dropped into the water and the flask thoroughly shaken. Naturally the characteristic alkali color appeared. This state was assumed to be that of a soil in good tilth. But practically all farming operations tend toward an acid reaction, so a few drops of dilute hydrochloric was added. The farmer was quick to note the solution's change from red to yellow, but when the flask was agitated a few times and the alkali color returned, he was amazed. When the phenomenon was explained to him in a manner that applied to the soil, he was apparently convinced that the beneficial action of limestone in the soil continued as long as there was any present.

This demonstration proved to be very popular and absolutely settled a number of arguments. It is hoped that lecturers on limes and liming will be able to make use of the method, as the materials required take up little room and are found in practically all laboratories.

[1] Contribution from the Maryland State Agricultural Experiment Station, College Park, Md. Received for publication November 13, 1917.

GLANDULAR PUBESCENCE IN VARIOUS MEDICAGO SPECIES.[1]

ROLAND MCKEE.

In a study of the occurrence of glandular pubescence in the various species of Medicago, an attempt was made to determine to what extent this character varies with environmental conditions. It has been observed that glandular pubescence is much more strongly developed in some species than in others. Certain species of Medicago have glandular pubescence on stems, leaves, and pods; others on the pods only; while some have none at all. Of the species studied the following have glandular pubescence strongly developed on the pods at least: *M. soleirolii, M. rigidula, M. minima, M. disciformis, M. blancheana, M. tunetana, M. falcata viscosa,* and *M. gaetula.* Other species having glandular pubescence less well developed or showing only under certain conditions are *M. murex sorentinii M. orbicularis, M. lupulina,* and *M. sativa.*

In some species of Medicago it has been noted that very minute glandular hairs may be present on the young green pods and disappear with later development. In other species in which only minute glandular hairs occur early in the season, both young and mature pods have well-developed glandular hairs later during hot, dry, and adverse weather conditions. Thus in plants in which glandular hairs can be noted on the pods early in the season only with a low-power compound microscope, glandular pubescence is quite strongly developed later in hot, dry weather.

Inasmuch as subspecific distinctions have been made in various species of Medicago on the presence or absence of glandular pubescence, the variability of this character is of value in determining the validity of such classification. In these studies *M. lupulina* and *M. orbicularis* have been especially noted. Individual plants have been observed throughout the season with regard to glandular pubescence development.

On April 27, 1915, at Chico, Cal., a plant of *M. orbicularis* was observed as having both young and well-developed pods that were not glandularly pubescent as the term is usually used but had glandular pubescence which could be seen with a low-power compound micro-

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

scope. On May 27, 1915, this same plant was noted as having both young and mature pods with well-developed glandular pubescence, that is, the glandular pubescence was sufficiently well developed to be seen without magnification. On April 27, 1916, at Chico, Cal., the pods of a plant of *M. orbicularis* were observed as not glandular. The most advanced pods were well developed but not mature. A hand lens only was used in making this observation. On May 27, 1916, at which time some of the pods were mature, this same plant was noted as having pods not glandular, while on July 7 it was noted as having both young and mature pods that were very glandular. General observation of numerous plants of *M. orbicularis* and its subspecies in the field have shown that early in the season none of these has pods in any stage of development that show glandular pubescence, while later in the season or after hot, dry weather has prevailed for some time practically all plants have pods in all stages of development with strongly developed glandular pubescence. In *M. orbicularis* glandular pubescence has been observed in no case as occurring other than on the pods.

Observations made regarding glandular pubescence in *M. lupulina* show the same fluctuating variation due to environmental conditions as that noted in *M. orbicularis*. However, there are also some indications that in this species some forms have glandular pubescence throughout their existence regardless of environmental conditions while others are never glandular. In the common form of this species, wherever observed, glandular pubescence is not present early in the season regardless of the stage of development of the plant, while later in the season it is quite conspicuous. In *M. lupulina* glandular pubescence may occur on the stems, leaves, and pods, but when not well developed it is most conspicuous on the pods. Plants of *M. lupulina* collected at Chico, Cal., on May 18, 1909 show young pods glandular. Plants collected at Chico June 5, 1912 show no glandular pubescence. Plants collected at Chico May 6, 1914, while in general not glandular, show a very few glandular hairs forming. Plants collected at New London, Ohio, June 28, 1915 show pods mostly non-glandular but with few glands forming. On April 27, 1915, at Chico, Cal., a plant of *M. lupulina* having pods well developed was observed as not glandular. On July 15 this same plant was noted as very glandular. On April 26, 1916 a plant of *M. lupulina* was observed at Chico, Cal., as not glandular. On May 8, 1916 this same plant was noted as not glandular, while on July 13, 1916 it was noted as very glandular. A plant of *M. lupulina* growing at Elyria, Ohio, was ob-

served on June 19, 1917 as not glandular. This same plant on August 23 was noted as not glandular, while on October 18 it was noted as very glandular.

In the summer of 1916 a plant of *M. lupulina* growing at Albany, Ore., was observed as not having glandular pubescence, while at the same time plants growing nearby were quite glandular. Seed from the non-glandular plant was collected and grown at Chico, Cal., in 1917. At no time did the plants grown from this seed show glandular pubescence.

From observations made in the cases of *M. lupulina* and *M. orbicularis* it is very evident that the occurrence of prominent glandular pubescence may be due to environmental conditions, these conditions apparently being hot, dry weather and unfavorable soil-moisture supply.

Some interesting observations have been made with regard to glandular pubescence in various varieties and hybrid forms of *M. sativa* and *M. falcata*. A large number of introductions of these species and subsequent hybrids made from these introductions have been observed to determine to what extent glandular pubescence might occur. Aside from one introduction of *M. falcata*, which had been identified as *M. falcata viscosa*, none have strongly developed glandular pubescence. However, glandular pubescence developed to some degree has been noted in a number of *M. falcata* forms. In the case of *M. sativa*, or common alfalfa, glandular pubescence was found in only two instances. In the case of *M. falcata* (excepting *M. falcata viscosa*), and also in *M. sativa*, the glandular forms are apparently hybrids, though they show but little variation in other characters.

On April 28, 1915 the pods of a large number of species of Medicago were examined to determine the presence or absence of glandular pubescence in species in which it might occur. Both macroscopic and microscopic observations were made. In such species as *M. scutellata* and *M. rugosa*, in which glandular pubescence is always present, long, well-developed glandular hairs were very conspicuously present to the unaided eye. In other species, such as *M. orbicularis*, which has strongly developed glandular pubescence in midsummer, glandular pubescence was present but only microscopically. Other species, such as *M. hispida* and its subspecies, which have not been noted as glandular late in the season, had microscopic glandular pubescence on the young pods. In a number of species the glandular hairs per square millimeter were counted and the length of the hairs and the length and width of the glands were determined.

In the case of *M. orbicularis* the maximum length of the hairs was 63 microns, while the glands of maximum size were 36 × 20 microns. Later in the season the glandular pubescence of this species measures practically the same as *M. scutellata*, the hairs being about 600 microns in length and the glands about 50 microns in length. In the case of a number of species such as *M. hispida, M. echinus, M. obscura helix, M. intertexta,* and *M. tuberculata aculeata,* microscopic glandular pubescence was noted on the pods early in the season, but in no case have these been noted as developing further.

The number of glandular hairs per square millimeter varied considerably in the different species. In the case of *M. scutellata* and *M. rugosa,* in which species the glandular hairs were well developed, the number was so many that they could not be definitely counted. With the species having only microscopic glandular hairs the number varied from 40 to 120 per square millimeter.

The data here presented seem to show clearly that in certain species of Medicago glandular pubescence varies decidedly with environmental conditions, and for this reason it can not be depended upon as a constant character in determining subspecies.

CUTTHROAT GRASS (*PANICUM COMBSII*).[1]

C. V. Piper.

Panicum combsii Scribner and Ball was described[2] from specimens collected "in damp, fertile flat woods" at Chipley, Washington Co., Fla., in the northern part of the State. Hitchcock and Chase[3] record it from three localities in southern Georgia, four stations in northern Florida, and one station each in southern Alabama, southern Mississippi, and southern Louisiana, and give as its usual habitat "margins of ponds and wet woods." From these data it would appear to be a rare species. During the past season the writer found it enormously abundant in Polk County, central Florida, where it is known as "cutthroat grass," and the peculiar areas in which it occurs

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication February 4, 1918.

[2] Scribner, F. Lamson-, and Ball, Carleton R. Studies on American grasses. U. S. Dept. Agr., Div. Agrost. Bul. 24: 42–43, fig. 16. 1901.

[3] Hitchcock, A. S., and Chase, Agnes. The North American species of Panicum. Contr. U. S. Natl. Herb. 15: 106–107. 1910.

in nearly pure growths are known as "cutthroats." The grass is said to be abundant in similar areas in Osceola County to the eastward, and in De Soto and Lee counties to the south. A "cutthroat" usually if not always occurs on seepage areas on the sides of slopes, especially of sand ridges. At these seepage places an abundance of water exudes, so that even in extremely droughty seasons, as in the spring and early summer of 1917, water can be obtained at shallow depths, a fact utilized by stockmen. The soil of a "cutthroat" consists of a very fine, slippery, black muck a foot or more in depth. These areas are treacherous, and in spite of the heavy cover of grass wagons and automobiles easily become bogged. Such areas vary in size from one to many acres, and often successions of them occur up the side of a gentle slope.

Cutthroat grass grows in dense tufts, the tough wiry leaves being nearly erect and 6 to 18 inches long. In typical cutthroat soil the plant rarely blooms. In the neighborhood of Florinda, Fla., however, abundant specimens were found in late bloom November 4, 1917.

According to Mr. W. F. Ward, the superintendent of the Kissimmee Island Cattle Company, the stockmen of the region are in accord as to their experience with this grass as a forage. They consider it good fattening winter feed for adult steers and for non-pregnant cows, but that pregnant cows abort when pastured on this grass, and that young animals die. So fixed is this opinion that stockmen govern their operations accordingly. Locally the disease is known as "salt sickness." "Salt sickness" has several times been investigated in Florida. Stockbridge, French, and Ennis[4] summarize their investigations as follows:

1. The disease known locally as "salt sickness" is not believed to be a specific *disease*, but rather a *condition* resulting from improper environment, especially insufficient nutrition.

2. Similar occurrences have existed elsewhere and are usually confined to regions where the predominating soil is light, sandy, comparatively lacking in nutritious qualities, Cape Cod peninsula in Massachusetts being a locality similarly affected.

3. The condition is most prevalent at the end of the winter season, when animals have been for several months confined upon range or pasture consisting of the dry wire-grass and other inferior vegetation of the sand ridge portion of the State.

4. The disease is distinctly digestive in character, has its seat in the alimentary canal and finally develops into chronic inflammation of the small intestine, resulting in malnutrition, anæmia and frequent death from starvation.

[4] Stockbridge, H. E., French, W. E., and Ennis, J. E. Salt sickness. *In* Fla. Agr. Expt. Sta. Rept. 1900–01, p. 43–58. 1902.

5. The symptoms show those generally attendant upon chronic anæmia: loss of flesh, loss of appetite, or abnormal appetite, including craving for foreign substances like earth, sand and bone, and diminishment of red blood corpuscles, as evidenced by thinness of blood, swelling or ulceration under the jaw and white bloodless appearance of mucus membranes particularly inside of the mouth and eyelids.

6. Alimentary correctives and tonics are suggested as counteracting these conditions.

7. The change of affected animals to new range or pasture is both preventive and curative in effect.

8. The use of lime water and gentian or iron salts have proved invariably beneficial and during our investigation of the subject not an animal thus treated died, but all eventually recovered normal condition. Air-slacked lime ½ ounce, and sulphate of iron ⅛ ounce, are recommended in 3 gallons of water, the former as often as the animal will drink and the latter daily.

Similar conclusions are reached in a separate publication by Dr. W. E. French.[5] Dr. C. F. Dawson,[6] however, reaches a different conclusion:

From what I have seen of "salt-sick" and from what we know of Texas fever, the rôle which it should play in diseases of cattle in the South, and especially in Florida, where the tick is ever-present, I am forced to believe that "salt-sick" is chronic Texas fever and that the conditions named by Dr. Stockbridge as being the cause of the disease are not the *sole* causes, but are contributing causes. The loss of appetite which occurs early in "salt sick" cannot in all cases be attributed to poor pastures and it would occur, regardless of pasture conditions, in an animal attacked with Texas fever.

In all cases of "salt-sick" where I have had an opportunity of making a post-mortem examination, I have found the appearances to be those which are attendant upon the extreme anæmia which follows an attack of Texas fever. These are pale, watery blood, dropsical conditions, light-colored, bloodless liver and extreme emaciation. Most important of all was the occurrence in fairly large numbers of the germ of Texas fever in the red blood corpuscles, in the omental fringes, and of ulceration of the pyloric end of the fourth or true stomach.

The subject so far as "cutthroats" are concerned is one that merits careful investigations as the alleged facts seem to be connected with the grass. Botanically the subject is of interest because a grass otherwise rare is enormously abundant in the peculiar soil areas to which it is adapted.

[5] French, W. E. A study of salt-sick cattle. *In* Amer. Vet. Rev., 25: 985–991. 1902.

[6] Dawson, C. F. Texas cattle fever and salt sickness. Fla. Agr. Expt. Sta. Bul. 64. 1902.

A DRILL FOR SEEDING NURSERY ROWS.[1]

C. E. Hill.

In view of the large amount of nursery sowing of field crops done on experiment stations, any implement which will save time and labor and eliminate mixtures of varieties or strains in seeding is of value. A drill which has these advantages has been devised by the writer. The merits claimed for the drill include the following:

1. Greater speed.
2. Greater accuracy.
3. Operation by one man.
4. Elimination of mixtures.
5. Seeding can be done on a windy day.
6. Better germination can be obtained than in hand seeding.

The essential parts of the drill are a funnel into which the seed is dropped by hand at the desired rate; a furrow opener; a tube which carries the seed from the funnel to the furrow opener; and a carriage on which these parts are mounted. The tube is long enough to permit the operator to walk with the body erect while seeding and wide enough to prevent any seed from lodging.

The type of carriage can vary somewhat and yet be satisfactory. A carriage having three wheels, two in front and one in the rear behind the furrow opener, is recommended. This type of carriage will stand without support and can be guided easily.

The front wheels are adjustable on the axle so that when the distance between the rows to be planted is not greater than 1½ feet they can be made to mark the rows by adjusting the distance between the wheels. After sowing the first row the other rows will be spaced properly by running one front wheel on the row previously sown. Rows more than 1½ feet apart can be marked by having an extension rod marker attached to the drill.

The drill is pushed by the body in contact with a padded curved band, attached to the frame of the drill at about the height of one's waist line. It is guided by one hand on the frame in front of the body. The other hand is used in dropping the seed into the funnel.

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

The depth of seeding is regulated by an extension sleeve on the furrow opener.

Seed in envelopes for sowing 100 or more varieties can be carried in a box conveniently placed on the frame of the drill. If a seeding outline is made and the envelopes are arranged in order of sowing, it is not necessary to label the rows until the seeding is completed.

The drill is recommended for sowing short nursery rows of different varieties or strains. With a little practice the rows can be seeded as fast as the drill can be pushed over the ground, as no time is lost in calibrating or cleaning the drill. If the envelope containing the seed is opened in the funnel the possibility of mixtures is eliminated, as the seed is carried directly to the ground in the row to be seeded and none can lodge in the drill. As drilling disturbs the surface soil but little, the seed usually can be drilled into moist ground at a uniform depth, insuring better germination than can be obtained by hand seeding into an open furrow. The drill is suitable for sowing light and fluffy seeds like tall oat grass (*Arrhenatherum elatius*), which will not feed through any of the ordinary types of garden drill. The drill is very simple in construction and can be made at a very low cost.

From these plans a drill essentially the same as the one described was made by Mr. F. J. Schneiderhan at the experiment station, Moro, Oregon, in 1917, from material available on the station. This was found satisfactory for sowing all kinds of seed and was used for all short-row seedings except where definite spacing of the seed was desired. It was also used in sowing long rows of light, fluffy seed that could not be seeded with a Planet Jr. garden drill. In his wheat nursery seeding, Mr. Schneiderhan was able to sow 350 rows 5 feet long per hour. Only 350 rows could be sown in a day by the method formerly used, which was to mark the rows to be sown, open the furrow, drop the seed by hand, and fill the furrows, making in all four operations. At the Moro station this drill was especially liked on account of its elimination of possible mixtures.

RED ROCK WHEAT AND ROSEN RYE.[1]

FRANK A. SPRAGG.

I wish to take a little of your time this afternoon in discussing some of the new products of the plant breeding work at the Michigan Agricultural Experiment Station.

When I took up the work ten years ago, our highest yielding wheats were white wheats of poor milling and of especially poor baking quality. The problem was to find a red wheat that would at least equal the white wheats in yield. This we are finding in the Red Rock, which originated from an individual plant selected in 1909. This strain was grown in a row in 1910, planted in the regular varietal series (twentieth-acre plat) in the fall of 1911, and distributed in peck lots through county agents in the fall of 1913. The Red Rock is a red wheat of exceptional winter hardiness, high yielding ability, an extra stiff straw, and those characteristics which make a bread of unusual quality.

The Rosen rye, on account of the exceptionally poor competitors, is yielding about twice as much as common rye. It has a shorter, stiffer straw than common rye and much larger heads, which are exceptionally well filled. There are four rows of kernels on every rye head, but the common rye has only scattering kernels along each row. The Rosen has four very nearly complete rows on 99 percent of its heads.

While I am talking about new pedigreed grains I want to mention the Michigan Winter barley. It has not proved as popular as the others, because it apparently does not fit into the rotation as well. It must be sown between August 15 and September 10 in order to produce a root system sufficient to stand the winter and give a good yield the next summer. When planted early on well-prepared, fertile soil, yields as high as 64 bushels to the acre have been reported. It matures before the wheat at a season of the year when the farmers usually need the grain to fatten their hogs. Unfortunately, however, on September 1 almost no land is available for the sowing of a fall crop.

[1] Contribution from the Michigan Agricultural Experiment Station, East Lansing, Mich. Presented by the writer, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

You may have heard of these pedigreed grains to some extent. They are spreading rapidly. Inquiries come to us from nearly every State in the central and eastern portions of the country, extending as far west as New Mexico, where a county agent has purchased the Red Rock wheat for sowing by his farmers this fall.

The distribution of the Rosen rye was started in Michigan in 1912, when about six bushels were distributed, mostly in bushel lots. It seems that we have to distribute to a number of people before we find one that will make the best use of a new thing, and in this case it seems that Carlton Horton, of Albion, was the only man who really took advantage of his opportunity. At that time pedigreed grains in Michigan were new and very little known. Mr. Horton planted his bushel on an acre and the next year got 35 bushels. The man who thrashed the rye and the neighbors who helped became very enthusiastic. so Mr. Horton thought he might easily have sold the rye at $5 a bushel for seed if he had cared to do so. This rye has spread through his own county, Jackson, until now the county agent tells us that almost no common rye is to be found. It has also very nearly replaced the common rye in St. Joseph County. It is estimated that 15,000 acres of Rosen rye were grown in Michigan in 1917 and 250,000 acres sown for the season of 1918.

The distribution of Red Rock wheat began in 1913 by the sending out of peck samples to a number of county agents. I will just mention a few samples and results. The peck that went to Allegan County was sowed on the farm of John Odell, about six miles south of Allegan, on his garden patch in 1914. It produced at the rate of 55 bushels to the acre. He sowed six acres that fall and in 1915 had seed for sale. Though he and County Agent Cook advertised it, the people knew it was a bearded wheat and did not buy until some of the seed had been ground by the local miller, who then became enthusiastic. The favorite trick of the miller was to have two bushels, well cleaned and closely tied in a sack, sitting near so that when a farmer came in the miller invited him to lift the sack. When Mr. Farmer did not lift it at arm's length, he inquired what it was. The miller told him that it was the only wheat grown in Michigan from which he could really make good bread, and on the recommendation of the miller the farmers sowed the seed and kept it pure until in 1917 there was 300 acres of this wheat in Allegan County still pure enough to pass the inspection as pedigreed grain.

The peck sample that went to Kent County became mixed, and though there were 100 acres grown in 1917 it could not be used for

pedigreed grain. The peck sample that went to Newaygo County in 1913 has been cared for by the county agent and in 1916 had been increased to 700 bushels. Four hundred bushels of this went to Kent County to replenish their supply of pure seed. I will just mention one other county. That is Houghton, on the Upper Peninsula, reaching into Lake Superior. Mr. Geismar is county agent there. During the years 1914 and 1915 he acclimated this wheat so that in 1916 it produced a fine crop on the county farm at Houghton. From this seed fields were grown in Houghton, Ontonagon, Marquette, and Delta counties in 1917. Thus, the Red Rock wheat when sown August 15 is proving successful in a spring wheat district.

It is estimated that 4,000 acres of Red Rock wheat were raised in the State in 1917 and that 100,000 acres were sown for the 1918 crop. The demand for this grain has been so great that just at the end of the campaign I received a letter from a farmer who stated that he had failed to obtain any Red Rock for seed and wished to have his name put on the list to receive some next season.

A representative of the Federal Bureau of Markets, Mr. Frank, who was looking up samples of our Michigan wheats in the fall of 1917, saw a large number of samples of Red Rock that had been sent in by the various growers as samples that they guarantee to be just what they were selling. Some of these samples weighed as high as 64 pounds to the bushel, while others had not been allowed to pass the grain inspection because of light weight, smut, or mixtures of other varieties. Mr. Frank obtained nine 2-bushel lots from farmers, ranging from the best to the poorest, for a milling test. He is of the opinion that a special grade will be given to Michigan into which only Red Rock is good enough to fall.

The distribution of our pedigreed grains has been aided greatly by the county agricultural agents, working in connection with the Michigan Crop Improvement Association, of which Mr. J. W. Nicolson is secretary. The members of this association are in general the most up-to-date and progressive farmers in their districts. Selected members of the association receive small samples of new crop varieties from the experiment station. There are also general demonstrations that are offered to members, for which the association must buy the seeds. The members get the benefit of the advertising of the association and the sale of pedigreed seeds when they have any that are acceptable. The expenses of the association are, first, the cost of the seeds for demonstration purposes, except such as are furnished by the plant-breeding work. Because of the

size of the association, this latter is simply a start. Other expenses include the salary and the traveling expenses of the inspector, the advertising in State, county, and agricultural papers, and the printing of seed lists of growers. There is no State aid for this distribution work as there is in Wisconsin. All the expenses must be paid out of the membership and inspection fees, except for the printing of circulars informing the farmers of the benefits derived from the raising of these grains.

The membership fee is $1 a year. If the individual is isolated the inspection of pedigreed grain costs him $10, of which he sends $6 with his application for inspection and pays the remainder when the field is inspected, if it is allowed to pass. If three or more members can be reached in a single day by the inspector, then the inspection fees are reduced by half. The farmer who is really benefitted by the raising of pedigreed grains must sow the new grains on clean land, with a clean drill, out of clean sacks. He must treat the grain for smut. He must pull weeds such as vetch and cockle while in bloom; in fact, he must remove all weeds that can not be screened out after thrashing. He must pull out all mixtures of other grains, such as rye in wheat, and if his wheat contains more than 1 percent of other varieties these must be removed, according to the requirements of 1917. The inspection is going to be more and more strict as the time goes on. The farmer must apply for inspection and entertain the inspector unless he is being taken care of by a county agent.

The farmer must clean his binder and thrasher to prevent mixtures. Fall grains like wheat or rye should be thrashed after oats. Most of the oats will be cleaned out in fanning, while those that remain will be frozen out during the winter. That is one of the advantages Michigan has over the West and South, where spring grains often volunteer. In thrashing oats after wheat, it is well to watch until no more wheat can be seen and then discard a few more bushels to be sure. If the thrashing machine is not cleaned in this way then at least 25 bushels must be discarded in saving seed for sale. Of course, no one stands over the farmer with a stick to make him do this, but these are the general rules that we feel must be obeyed or his grain will not be able to pass the grain inspection. He must fan his grain at home, for if he sends it to an elevator he gets it mixed beyond redemption. He must remove all weed seeds, all smut balls, and shriveled kernels that will not produce thrifty plants. Then he must send the secretary of the association a peck

sample of the grain just as he expects to sell it. If this grain is to pass the second inspection it must be free from weeds, up to standard weight, and contain less than 1 percent of mixture of other varieties. If his grain is passed he receives the association's shipping tags and report cards. His name is put on printed lists of growers who have seed for sale. The association does the advertising and those who inquire as to where they can purchase good pedigreed grains are sent these printed lists. The growers also certify on the back of the shipping tags. For instance, if it is Red Rock, "The wheat in this bag is Red Rock; it grew on a field inspected by an agent of the association; it conforms to the State seed law, and it conforms to sample submitted to the association for inspection." This certification is the purchaser's guarantee that the seed is as it is supposed to be, and is binding upon the grower to the extent that he must refund the money or make it right. Several did this last fall. For instance, one grower in Allegan County refunded $1 a bushel on some seed that had evidently not been recleaned.

THE IDENTIFICATION OF VARIETIES OF OATS IN NEW YORK.[1]

E. G. Montgomery.

During the summer of 1917, Mr. George Stewart, one of the graduate students in farm crops at the New York State College of Agriculture, undertook as a part of his graduate work to make a practical test of Dr. Etheridge's key to oat varieties[2] under field conditions. Samples of oats were collected from New York State seedsmen and grown in the garden for identification, and also oats growing in fields were examined and identified. In addition, varieties growing at two experiment stations were also examined. Some of the results as worked out by Mr. Stewart are here given.

The varieties offered by certain seedsmen and their identification were as follows:

[1] Contribution from the Department of Farm Crops of the College of Agriculture, Cornell University, Ithaca, New York. Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Etheridge, W. C. A classification of the varieties of cultivated oats. N. Y. (Cornell Univ.) Agr. Expt. Sta. Memoir 10, 1916.

Seedsman's name.	Identification according to key.
Seedsman A	
Winter or Turf	Winter Turf.
Imported Clydesdale	Swedish Select.
Early Newmarket	Do.
Swedish Select	Do.
Long's White Tartar	Tartar King.
Imported Black Tartarian	Black Tartarian.
American Clydesdale	Swedish Select.
Probsteier	Do.
Long's Storm King	Storm King.
White Russian	Storm King or Tartar King.
Seedsman B	
Tartar King	Tartar King.
Canada Cluster	Swedish Select and Storm King.
Seedsman C	
Michigan	Lincoln and Belyak.
Seedsman D	
Northern Wonder	Swedish Select.
Seedsman E	
Alberta Cluster	Swedish Select.
Seedsman F	
Golden Fleece	Swedish Select and Storm King.
Bumper Crop	Storm King and Swedish Select.
Long's White Tartar	Storm King and Swedish Select.
Seedsman G	
Alberta Cluster	Swedish Select.
Seedsman H	
Heavy Weight	Swedish Select.
Twentieth Century	Belyak.
Seedsman I	
Swedish Select	Belyak.

Where two varieties were identified, the dominant type is named first. Out of 10 varieties offered by Seedsman A, 5 appeared to be straight Swedish Select, if the identification is correct. When this identification was presented to the seedsman, he stated that four of the varieties identified as Swedish Select were imported from England, which would indicate that in Europe also they are using several names for what appears to be the same variety. Of course, there may be differences in adaptation or quality not discernible in a botanical examination, but at least to all outward appearances the varieties are identical.

Of the 22 varieties listed above, 11 are of Swedish Select type and 2 more contain an admixture of Swedish Select. This would indicate that this type has been found best for the State.

The varieties grown at one experiment station, together with the identifications found, were as follows:

Experiment station name.	Identification according to key.
1. Silvermine	Silvermine.
2. White Russian	Swedish Select.
3. Corn Belt	Lincoln.
4. President	Lincoln and Swedish Select.
5. Wideawake	Irish Victor.
6. Napoleon	Swedish Select and Lincoln.
7. Siberian	Swedish Select, Lincoln and June.
8. Burt	Burt.
9. White Probsteier	Lincoln and Swedish Select.
10. Golden Fleece	Swedish Select.
11. White Plume	Storm King.
12. Joanette	Joanette.
13. Canadian Side	Storm King, Lincoln and Belyak.
14. Hvitling	Lincoln and Belyak.
15. Lincoln	Lincoln and Silvermine.
16. Sixty Day	Kherson.
17. Welcome	Silvermine or Scottish Chief.
18. Czar of Russia	Swedish Select, Lincoln and Silvermine.
19. Black Mogul	Black Norway (?)
20. Clydesdale	Silvermine and June.
21. Big Four	Belyak, Silvermine, and June.
22. Seizure	Green Mountain.
23. Alaska	Lincoln, Belyak, and June.
24. American Banner	Belyak and Lincoln.
25. Morganfeller	Silvermine, Lincoln, and Belyak.
26. Swedish Select	Swedish Select.
27. Long's White Tartar	Storm King.
28. Golden Rain	Golden Drop.
29. Sparrowbill	White Tartar and Storm King.
30. Improved American	Lincoln and Swedish Select.
31. Beardless Probsteier	Awnless Probsteier.
32. Green Mountain	Lincoln.
33. Ellwood	Belyak and Silvermine or Scottish Chief.
34. Victory	Lincoln and Silvermine.
35. Early Champion	Irish Victor.
36. Sensation	Lincoln, Swedish Select, and Early Gothland.
37. Twentieth Century	Lincoln, Swedish Select, and C. I. 602.
38. Storm King	Storm King.
39. White Ligowa	Swedish Select.
40. Detmer's New Bumper	Storm King.

The above list is given to illustrate the situation that probably exists at all of the experiment stations where varietal tests are under way and emphasizes what has heretofore been pointed out, the need of a careful study of varietal nomenclature and the standardization of names.

In order to get some idea in regard to the type of oats grown by

New York State farmers, examination was made of a strip of country across the State from north to south, which is believed to be fairly representative. In all, 418 fields were examined with the results shown in Table 1.

TABLE 1.—*Number of farms on which certain varieties of oats are grown in Cortland, Tioga, Cayuga, Tompkins and Ontario counties, New York.*

Variety.	Virgil, Cortland Co.	Owego, Tioga Co.	Auburn, Cayuga Co.	Moravia, Cayuga Co.	Ithaca to Dryden, Tompkins Co.	Ithaca to Trumansburg, Tompkins Co.	Western Ontario Co.	Eastern Ontario Co.	Total
Lincoln	7	15	15	17	7	31	18	8	118
Swedish Select	11	6	10	20	9	15	30	9	110
Belyak	3	3	5	1	3	20	9	3	47
Silvermine	7	8	3	1	8	5	17	8	57
Canadian	4		14	7	3				28
Storm King	4	10	4	1	2	3	8	2	34
Sparrowbill			1	3					4
June		1		1				1	3
Old Island Black				1					1
Irish Victor			2		1		1	3	7
Tobolsk			1		1				2
Danish Island			3						3
White Tartar						2		2	4
Total	36	43	58	52	34	76	83	34	418

The figures given in Table 1 show the following percentages of the different oat varieties in central New York State:

Variety.	Per Cent.
Lincoln	28.2
Swedish Select	26.3
Silvermine	13.6
Belyak	11.3
Storm King	8.1
Canadian	6.7
All others	5.8
	100.0

The summaries show that 79.4 percent of the oats were identified as Lincoln, Swedish Select, Belyak, and Silvermine. These varieties are very similar and can hardly be distinguished from each other except by a trained observer. The indications are that long experience of both the seedsmen and farmers have shown this type to be the best adapted to the State.

ORIGIN OF THE GEORGIA AND ALABAMA VARIETIES OF VELVET BEAN.[1]

H. S. Coe.

For many years the Florida velvet bean (*Stizolobium deeringianum* Bort) has been grown in Florida and the extreme southern part of the Gulf States as a soil-improving crop and for grazing. In other portions of the South the value of this plant was limited, as it required a frost-free season of eight to nine months to nature. Even though only a portion of the pods usually matured in the southern half of the Gulf States, many farmers valued this crop so highly for grazing and for soil improvement that they planted it annually.

As the United States Department of Agriculture recognized the value of an early-maturing velvet bean which would produce winter grazing equal to that of the Florida variety and which would mature in most parts of the cotton belt, a careful search was made for such a plant in other countries. The Chinese velvet bean was introduced from Tehwa, China, and the Yokohama velvet bean from Yokohama, Japan. Both of these plants mature earlier than the Florida variety but their pods have the undesirable characters of splitting and shattering the seed when mature. The Chinese variety is superior to the Florida for the southern portion of the Gulf States, but it rarely matures in the northern part of the cotton belt. The Yokohama matures in about 120 days, but it produces a small vine growth and most of the pods are formed so close to the ground that in a relatively short time they decay. However, before either of these species was introduced, two early maturing mutants of *Stizolobium deeringianum* were found in southern Georgia, although they were unknown to the public for several years.

In the spring of 1906, Mr. Clyde Chapman of Sumner, Ga., planted a field of corn and Florida velvet beans. The following August, several hills of mature beans were found in this field. The seed collected from these early-maturing plants was planted in corn the following year and early plants were produced, similar to those found the previous year. A small quantity of the seed grown in 1907 was distributed to several of Mr. Chapman's neighbors, but so far as

[1] Contribution from the Office of Forage-Crop Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication January 24, 1918.

known none of this seed was sent out of this immediate section prior to 1912, with the exception of one lot sent to Schley County, Ga., in the spring of 1909. The seed of the Florida velvet bean planted in the spring of 1906 was obtained from Mr. Z. C. Allison, of Sumner, Ga., a relative of Mr. Chapman's. Three or four years prior to this date Mr. Allison obtained seed of this particular strain from a field in Schley County, Ga., and each year enough seed matured on his farm for seeding the following spring.

The first early-maturing plants noted by Mr. Chapman made a small vine growth, matured their first pods in 90 to 100 days from planting, and produced seed which, according to Mr. Chapman, was somewhat paler and slightly smaller than the seed of the Florida velvet bean. From the first the plants of this early-maturing variety came true to type.

Another mutant of the Florida velvet bean was found by Mr. R. W. Miller, of Broxton, Ga., in August, 1908, in a field planted to corn and Florida velvet beans. The velvet bean seed planted in this field was grown in Florida. The seed of these early-maturing plants was sown in 1909 and, according to Mr. J. D. Harrell, of Douglas, Ga., a relative of Mr. Miller's, the plants came true to type. Mr. Harrell obtained some seed from Mr. Miller in the spring of 1910 and that year harvested 15 bushels. So far as known, the seed of this mutant was not generally distributed by Mr. Miller or Mr. Harrell, but Mr. W. A. Clark, of Jacksonville, Ga., obtained seed from Mr. Harrell in 1913, and later sold seed of this variety under the name of "Clark's velvet bean." This bean, so far as can be determined, is identical with the one found by Mr. Chapman. In investigating the origin of this mutant, not the slightest evidence was found to indicate that the early-maturing plants found by Mr. Miller could have been produced from seed grown by Mr. Chapman.

A third mutant of the Florida velvet bean was found by Mr. H. L. Blount, of Flomaton, Ala. Mr. Blount, who had grown velvet beans as a grazing crop for at least fifteen years, obtained seed from Florida, which he planted with corn in the spring of 1911. In a sandy gap in this field, one plant was observed which bloomed much earlier than any of the others. By October 20, and before frost, all of the seed on this plant was matured and the plant was dead. About 1½ pints of seed were collected from it. This seed was planted along a fence row in 1912, and that fall several bushels of seed were harvested. In the spring of 1913, 50 to 60 packages of this seed, varying in size from one half pint to one quart, were

sent to farmers in Alabama, Mississippi, and Georgia for trial, and the remainder of the 1912 crop was planted in corn on Mr. Blount's farm. In 1914 seed of this variety was sold to a number of Alabama farmers and to the Alabama Agricultural Experiment Station. Mr. Blount stated that as soon as he found the early-maturing plant he wrote to the person in Florida from whom he purchased his seed, asking him if he had observed early-maturing plants in his fields. The reply stated that an early-maturing velvet bean had

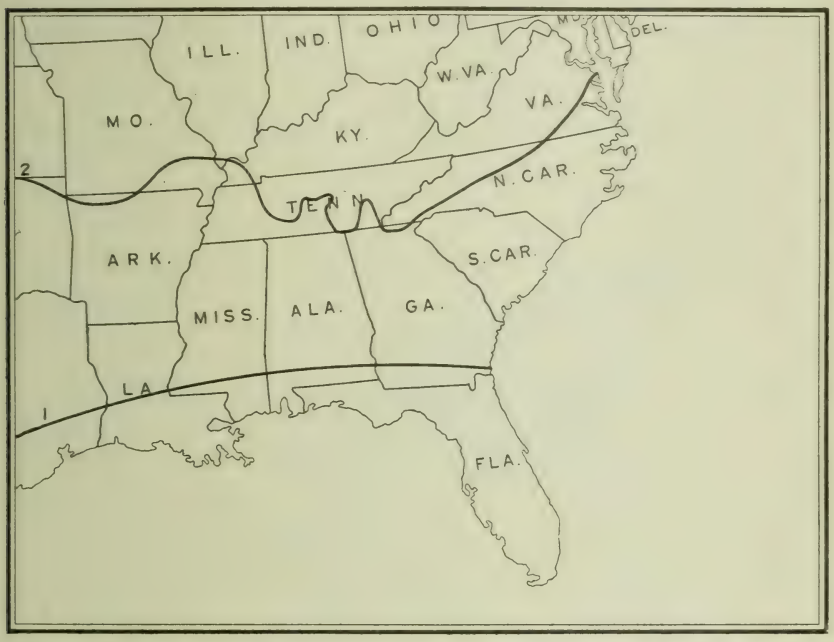

FIG. 25. Map showing the extension of the velvet bean area by the introduction and discovery of early maturing varieties. The Florida velvet bean will seldom mature fully north of line No. 1, while the Georgia variety will mature south of line No. 2.

never been observed by the writer. The early-maturing plant found in 1911 made a somewhat smaller vine growth and produced slightly smaller and somewhat paler seed than the Florida velvet bean, but it made a larger vine growth than the early-maturing varieties found by Mr. Chapmen and Mr. Miller. This variety matured fully in 170 to 180 days, or about two months earlier than the Florida velvet bean. It is known as the Alabama velvet bean.

The N. L. Willet Seed Company, of Augusta, Ga., the Office of Forage-Crop Investigations, the Office of Extension Work in the

South, and Mr. Clifford Grubbs, manager of the Farmers' Produce Exchange, of Sylvester, Ga., were largely responsible for the general distribution of the early variety discovered by Mr. Chapman. Mr. Willet purchased about 200 bushels of seed of this variety from a neighbor of Mr. Chapman's in the fall of 1914. This seed was sold to the seed trade in the spring of 1915 under the name of "Hundred-Day Speckled." Twenty bushels was purchased from the N. L. Willet Seed Company by the Office of Forage-Crop Investigations in the spring of 1915 and distributed in small packages in different sections of all of the Southern States in 1915 and 1916. The Office of Extension Work in the South purchased a quantity of seed of this variety at Atmore, Ala., in the spring of 1915. Some of this seed was sent to each county agent in Alabama and Mississippi, and to a few agents in Louisiana, eastern Texas, and South Carolina for planting on demonstration farms. Mr. Clifford Grubbs shipped to many points in the South the surplus grown by the farmers living in the vicinity of Sumner. The first shipments were made in 1913 and about 25 bushels were sold. In 1914 approximately 100 bushels and in 1915, 500 bushels were distributed in this manner.

The Office of Forage-Crop Investigations has suggested that the name "Georgia" be used in preference to "Hundred-Day Speckled" because the variety was first discovered in Georgia and further because it does not mature in 100 days, as the name "Hundred-Day Speckled" indicates. The first few pods may mature in that time but it usually requires 120 to 130 days for the entire crop to ripen.

It is probable that early maturing mutants of *Stizolobium deeringianum* have appeared elsewhere, but, if observed and isolated, no records have been obtained.

As both the Georgia and Alabama varieties have been distributed to all parts of the South, it is impossible to say in what percentage each contributed to the 1917 crop. As the Georgia variety was more generally distributed in 1915 and as much of the seed grown that year was sold for seeding purposes, it is assumed that the acreage of the Georgia was much larger than that of the Alabama in 1916 and 1917. It is believed that the Alabama variety will be planted most extensively in the southern portion of the cotton belt and the Georgia variety in the northern portion on account of the time required for each to mature. The Alabama variety makes a larger growth and therefore should yield more heavily than the Georgia in sections where the growing season is long enough for it to mature.

By the discovery and distribution of these early-maturing varieties the culture of velvet beans has been greatly popularized and has extended to the northern limits of the cotton belt (fig. 25). Not only has the area of adaptation been largely increased but the acreage of velvet beans has increased from less than 1,000,000 to over 5,000,000 in the past three years (fig. 26). The acreage in 1917 was 119 percent greater than in 1916. The direct and indirect value of this enormously increased acreage of a vigorous-growing legume will be a determining factor in improving the agricultural industry of the South, as the large quantity of nutritious feed produced by this crop at a low cost will stimulate the production of livestock. The net cash

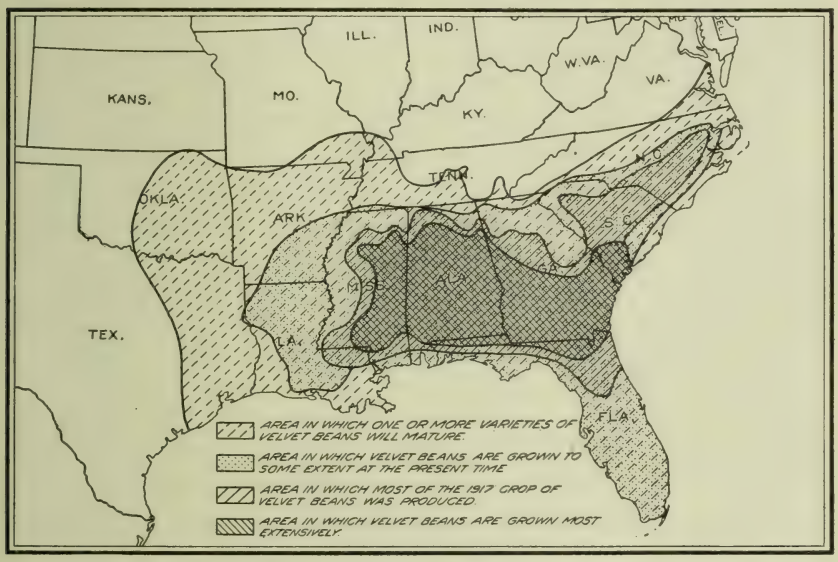

FIG. 26. Map showing the distribution of velvet beans.

value of the early-maturing velvet beans produced in corn was more than $20,000,000 in 1917. To the net cash value of the beans and pods may be added the value of the increased yields of subsequent crops, as the vines will be plowed under or pastured and when pastured but little of their fertilizing value is removed from the field. Experiments conducted by different experiment stations show that velvet beans are superior to cowpeas, beggarweeds, or soybeans for improving the soil. Therefore, it is believed that the value of the vines and roots of the 1917 crop for this purpose is at least twice as great as the cash value of the beans and pods.

THE VALUE OF BLUE LITMUS PAPER FROM DIFFERENT SOURCES AS A TEST FOR SOIL ACIDITY.[1]

P. E. KARRAKER.

Many workers in soils, through publications and otherwise, advise that farmers use the well-known blue litmus paper test as a qualitative field determination for soil acidity. A smaller number express doubt as to any great value attached to this test, especially in the hands of farmers, and some few think that the farmer should leave the test entirely alone. Barlow[2] has gotten together a number of

In the soils laboratory of the agronomy department of the Kentucky station it is the custom to use the blue litmus paper test to get an initial idea as to the reaction of the soil before employing the quantitative lime-water determination, and to a limited extent the test is used independently when only qualitative information is desired.

Kalbaum's blue litmus paper, a stock of which had been on hand since the fall of 1915, was used in this work. This paper is very sensitive and apparently has nearly always given accurate qualitative results. In addition it has afforded some information in a quantitative way. Recently, blue litmus paper tests were made in 32 soils. Afterwards, occasion arose to determine the limestone requirement of these soils by the Hopkins and also by the Veitch lime-water methods. In but one or possibly two instances was the qualitative information afforded by the litmus paper test at fault.

Lately in connection with the preparation of a practical bulletin on liming land, the question arose as to the proper time to leave the blue litmus paper strips in the soil. Reference to the literature showed a considerable diversity of direction on this point. For instance, Whitson and Weir[3] advise that the paper be left in 5 minutes; Abbott[4] about 10 minutes; Schollenberger[5] about half an hour; and Barker and Baer[6] as much as half an hour.

[1] Contribution from the Agricultural Experiment Station, University of Kentucky, Lexington, Ky. Received for publication December 13, 1917.

In Jour. Amer. Soc. Agron., 8: 26, 27. 1916.

[2] Barlow, J. T. Soil acidity and the litmus paper method for its detection. these published opinions.

[3] Whitson, R. A., and Weir, W. W. Soil acidity and liming. Wis. Agr. Expt. Sta. Bul. 230, p. 9. 1913.

[4] Abbott, John B. Liming the soil. Ind. (Purdue Univ.) Agr. Expt. Sta. Circ. 33, p. 12. 1912.

[5] Schollenberger, C. J. Acid soils and soil acidity. *In* Ohio Agr. Expt. Sta. Monthly Bul., p. 33. October, 1917.

[6] Barker, J. F., and Barr, W. W. Ground limestone for use in New York State. N. Y. State Agr. Expt. Sta. (Geneva) Bul. 430, p. 29.

It has been the custom in this laboratory to leave the litmus paper in the saturated soil only 5 to 10 minutes, usually only 5 minutes. In nearly all cases a distinct pink and often the maximum pink occurs in this time when the soil is acid. The color change occurring in a much longer period, 30 minutes or more, is not considered as trustworthy as that from the shorter period, as there is a tendency for a pink color to develop in this longer period whether the soil is acid or not.

Obviously the length of time that the paper should remain in the soil will depend on its sensitiveness. Litmus paper from different sources varies much in this respect. The worker is very likely to recommend the length of time best adapted to the paper with which he is familiar. If it were not for the tendency of a pink color to develop in time, particularly in heavy soils, even in the absence of an acid condition, a maximum time could be prescribed which would enable the color change to occur with litmus paper of all grades of sensitiveness. The fact that litmus paper from different sources does vary in sensitiveness and that a maximum time can not be prescribed on account of danger of appearance of a pink color during this time in the case of more sensitive paper irrespective of an acid soil condition, is on the surface a valid objection to the general use of litmus paper as a test for soil acidity.

To obtain some information as to the color change in acid soils of blue litmus paper from different sources, samples of the paper were gotten from different departments in the experiment station. Litmus paper from five different sources was thus secured. Requests were also made of a number of druggists through the State for samples of their blue litmus paper and samples obtained from ten of them. In a number of cases the paper was not in stock. These samples were compared with the Kalbaum's paper by testing in a soil which had a limestone requirement of 2,912 pounds as determined by the lime-water method.

The tests were made very much after the method used in laboratories of the Missouri station by laying the litmus paper slips on a watch glass and forcing the soil after it had been made into a mud ball well up against them by means of a second watch glass. This leaves the soil and litmus paper between two watch glasses with the paper directly against one glass so that the color change can be observed at any time.

Under these conditions, the Kalbaum's paper showed a distinct pink in 2 minutes, and the maximum pink color was reached in about 5

minutes. Of the five experiment station papers, two were found to be about as sensitive as Kalbaum's, one required an hour to show a slight pink, and two at the close of two hours showed very little or no pink at all.

The druggists' samples were compared with the Kalbaum's in the same way. In 5 minutes, as usual, the Kalbaum's paper gave a good pink. Of the druggists' papers, one gave a good pink and 3 others a slight pink. In 30 minutes, slight pink appeared in 3 more. At the end of two hours, a good pink was present in 4 of the druggists' papers, a fair amount of pink in 3, and a slight pink in one. In paper from 2 of these samples no pink color appeared at all.

When these druggists' papers together with the Kalbaum's were placed in one thousandth normal hydrochloric acid solution, the following color changes appeared. The maximum amount of pink appeared in the Kalbaum's paper in a half minute, and in the druggists' papers as follows: In one, in 1.5 minutes; in one, in 5 minutes; in two, in 8 minutes; in two, in 9 minutes; in one, in 15 minutes, in one, in 30 minutes; and in two, no pink color appeared at all. These latter two gave pink color in a strong acid solution. In the main, the sensitiveness of the papers as determined by the acid solution checked up closely with that observed in the soil.

Tests in the soil were made with a few neutral litmus papers from different sources, but the color change is not distinct enough to make the use of this paper advisable.

Tests were also made with the Kalbaum's blue litmus paper in a few soils of limestone origin which still contained limestone as shown by vigorous effervescence with hydrochloric acid, to determine whether a pink color would appear under these conditions. In a heavy subsoil a slight pink appeared at the end of 30 minutes; however, it was not permanent. In a lighter surface soil the paper always remained blue. There is no doubt, however, of the tendency for sensitive blue litmus paper to develop a pink color in soils of high colloidal content in the absence of an acid condition.

In part as a result of this limited study, it is thought inadvisable to recommend the blue litmus paper test to farmers as a means of testing for soil acidity. In the hands of an operator who is familiar with the paper he is using and knows what color changes to expect under various conditions, the test is a good qualitative one for soil acidity and in addition gives some information in a quantitative way, but for general use it can not be considered reliable and may give results which are entirely misleading.

PRIMITIVE METHODS OF MAIZE SEED PREPARATION.[1]

H. Howard Biggar.

The word "corn" in the Indian language has many forms. In the Sioux it is "wagamaza," in the Omaha it is "wahaba," in the Gros Ventre it is "holiati," in the Mandan it is "khati," while the Arikara calls it "nicissee." The word is one of the most important in the tribal vocabulary, since corn for generations was the main and often the only food plant.

In an investigation covering 15 Indian reservations in Minnesota, North Dakota, South Dakota, Nebraska, Montana and Manitoba, the writer was much impressed by the agricultural practices of the Indians in connection with their corn production. None of these practices are of more interest than the preparation of seed.

The Indian designated time by referring to natural phenomena. Seed was prepared and corn planted when the wild turnips began to bloom, when the grass began to become green, when plums, wild grapes, or juneberries began to blossom, when the leaves began to uncurl, or when the first prairie flowers began to bloom. Superstition and suggestive magic played an important part in seed preparation. Red Bear, an Arikara of the Fort Berthold reservation, informed me that the oldest woman of each family was usually intrusted with this work and that it was partly a secret process and almost a sacred one. It was Red Bear's opinion that since the old methods had been discontinued the cornfields of the Indians produced lower yields and the plants were more susceptible to insects and to plant diseases.

Various standards were used as the basis of seed selection. Many of the Indians have told me that moldy cobs on ears in the fall were very undesirable. For the most part, well-filled tips were sought as well as straight rows of kernels. The tip and the butt kernels were discarded and the middle kernels used for seed, the explanation being that these were better producers. Seed ears were braided together by the husks every fall, the braids being about 5 feet long.

Indian informants on the Crow Creek, Lower Brule, Rosebud, Yankton, Standing Rock, Fort Berthold, Fort Totten, and Red Lake reservations, representing tribes of the Sioux, Gros Ventre, Arikara,

[1] Contribution from the Office of Corn Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Received for publication February 2, 1918.

and Chippewa Indians, stated that it was always the custom to sprout the corn kernels previous to planting. The sprouting had a two-fold object, (1) to insure the plants coming up more quickly and (2) to insure a good stand of plants, since kernels not sprouting were at once discarded.

In the Red Lake reservation country of northern Minnesota, the Chippewa Indians had their fields bordering the lake and entirely around it. The lake country was densely wooded and hence use was made of moss in sprouting. Previous to planting, a box was filled with moss and kernels of corn placed in the moss. The whole was soaked for a time and then set in a warm place until the kernels sprouted. Dead kernels were thrown out and the sprouted ones were planted. Some tribes placed kernels in small sacks, soaked the sacks in water, and then hung them in a warm room to germinate. Others made willow baskets, filled them with kernels of corn, poured water through the corn, and then placed the baskets in a warm place.

Red Horse of the Yankton Reservation was the first to tell the writer of the use of the ground plum (*Astragalus caryocarpus*) in connection with the sprouting of seed corn. Later, members of other tribes corroborated his story. It is a custom among some tribes to soak the fruits of the ground plum in the same water in which the seed corn was soaked. The ground plum is the well-known prairie legume with a habitat ranging from Saskatchewan to Texas. Dr. M. R. Gilmore, State historian of North Dakota, believes that as the ground plum is prolific, bearing many fruits, the Indians thought its use would make the corn more productive. This explanation is in line with Indian beliefs. The Omahas in Nebraska placed the shell of a turtle in the water with the corn, believing that, as turtles eat insects, the use of the shell would aid in keeping the corn plants free from insect damage.

While the writer was visiting the Crow Creek Indian Reservation in South Dakota, Medicine Crow, Kill Dead, and Seeking Land gave the first information regarding what might almost be called a primitive ragdoll seed tester. Subsequently William Bean of the Yankton Reservation in South Dakota and Matokikta and Little Bull of the Fort Totten Reservation in North Dakota confirmed their statements. The main part of this primitive tester was the stem of the slender nettle, *Urtica gracilis*. The leaves of this nettle are sparingly armed with stinging hairs. After describing the plant, Medicine Crow took me into the near-by woods and showed me a clump of them. Large patches were also seen in the vicinity of Devil's Lake, N. Dak., on the

Fort Totten reservation. The Sioux Indian name for this nettle is "asbehu" or itch weed.

The slender nettle was used in the following manner. When the time for planting corn was at hand, quantities of the nettle were gathered. They were then piled up in a sort of mat and on this mat the kernels were placed. The mat of nettles was then rolled up so that it made a cylindrical bundle with the corn kernels on the inside. The bundle was tied round with strings cut from buffalo hide and then immersed in water. After soaking for a day or more, the bundle was removed, wrapped in a buffalo skin or some other covering, and kept warm. In a few days the kernels sprouted and when the sprouts were a quarter of an inch or more long they were planted. Kernels not sprouting or showing swollen germs were at once discarded. The slender nettle was used for this purpose instead of some other prairie plant because it was the first plant to reach any considerable height by corn-planting time. Further, the fact that the plant was protected with stinging hairs gave the Indian the superstitious idea that corn germinated with it would be protected from plant enemies during the growing season.

At the South Dakota State Fair at Huron in September, 1917, the Crow Creek Indian Agency exhibit included a nettle tester in which corn was being germinated. These testers have been used by the Indians for at least seventy-five years.

The principal corn grown by the Indians of the Middle West was the soft or flour corn, *Zea amylacea*. This type absorbs water more readily than the dent or flint types, as shown by the following experiment. One hundred grams of each variety were placed between wet bleached muslin and reweighed after 22 hours. The blue flour corn absorbed 18.0 percent of water; Reid yellow dent absorbed 13.5 percent; and U. S. Selection No. 193, a flint corn, only 6.6 percent.

THE TIME AT WHICH COTTON USES THE MOST MOISTURE.[1]

C. K. McClelland.

It has long been recognized that cotton can be produced with less water than is required for crops of corn and oats. Not only is this true, but apparently there is a great difference in the stage of growth when these crops require the maximum amounts of water. A dry

[1] Contribution from the Georgia Agricultural Experiment Station, Experiment, Ga. Presented by the author at the second annual meeting of the Association of Southern Agricultural Workers, New Orleans, La., in January, 1917. Received for publication February 10, 1918.

time occurring when corn or oats are filling and ripening noticeably reduces the yield, but with cotton a dry time during the maturing (opening) of the crop is to be desired. Probably, however, there is an analogy between the processes of growth which are taking place in the cotton and in the grains during the periods when each is using large amounts of water; that is, the blooming and boll-filling period of cotton rather than the opening should be considered the same period of growth as the blooming and head-filling or ear-filling periods of the grains. At this period of growth a dry time is equally as disastrous with cotton as with the grains, the effects being shown largely in the shedding of the squares or newly set bolls.

TABLE 1.—*Liters of water applied weekly from July to September, inclusive, to individual cotton plants grown in potometers in 1915, with the percentage of saturation at which each was maintained.*

Plant No.	Saturation, percent.	First period.			Second period.						Third period.	
		Week in July.			4th week July	Week in August.				1st week Sept.	Week in Sept.	
		1st.	2d.	3d.		1st.	2d.	3d.	4th.		2d.	3d.
17	60			3.5	12.8	6.6	19.6	19.9	31.0	15.5	26.5	19.9
24	60	3.5	3.5	28.0	28.7	35.4	24.0	24.3	42.0	11.0	26.5	22.1
6	75		5.3	15.7	19.9	26.5	37.6	35.4	33.2	19.9	26.5	13.2
18	75	3.5	7.0	14.0	23.4	44.2	26.5	31.0	37.6	17.7	19.9	15.5
29	75		1.8	14.0	13.2	22.1	28.7	26.5	35.4	11.0	26.5	22.1
14	90	1.8	21.0	22.8	39.8	50.8	28.7	28.7	28.7	6.6	28.7	15.5
23	90	1.8	3.5	17.5	24.3	42.0	28.7	28.7	26.5	6.6	28.7	4.4
22	30–60–90	1.8	1.8	14.0	18.4	15.5	15.5	31.0	22.1	13.2	33.2	24.3
7	90–30–60	3.5	17.5	15.7	6.6	13.2	2.2	22.1	11.0	6.6	15.5	8.8
30	90–30–60	3.5	15.5	24.5	6.6	28.7	24.3	24.3	15.5	4.4	31.0	4.4
Totals		19.4	77.1	169.7	193.7	285.0	232.8	271.9	293.0	112.5	263.0	150.2

Blooming records taken in different years may show a seasonal variation and naturally there will be some variation between varieties and likewise between individuals. In general, however, records of blooming will give a fairly good index to the time of year when the filling process begins. The time when the blooms are coming out most rapidly and the time when the plants are using the most moisture seem to be correlated. In experiments to determine the water requirements of cotton conducted at the Georgia station in 1915 and 1916, plants were grown in potometers and the quantity of water applied at different periods recorded. Table 1 shows the liters of water applied to the individual plants by weeks during July, August, and September. The number of blooms appearing each week on each individual and the number of blooms appearing on plants under field conditions each week are recorded in Table 2.

TABLE 2.—*Number of flowers opening weekly on individual cotton plants in potometers in 1915, with the number on 18 plants in the field.*

Plant No.	Total number of blooms.	Week in July.		Week in August.				First week Sept.
		Third.	Fourth.	First.	Second.	Third.	Fourth.	
24	84		6	10	21	24	20	3
18	67	1	5	10	18	18	13	2
14	67	2	10	11	18	17	9	
22	47		6	5	10	9	11	3
7	35	3	9	12	9	1	1	
Total	300	6	36	48	76	69	54	8
18 field plants	327		129	118	80			

Table 2 shows that the plants in the potometers began blooming the third week in July, increasing until the second week in August, and then decreasing. The record of 18 plants in the field showed that the greater number of blooms appeared there during the last week in July. This difference is due primarily to the fact that the plants in the potometers were from seed planted rather later than those in the field and even in most cases from replantings. The replanting was due to the destruction of the first plants by girdling with plastic clay in attempts to prevent evaporation and the penetration of rain water into the cans. The cotton plant is very tender in its earlier stages and is easily damaged by such treatment. If the supply of moisture remains constant, blooming may be delayed. This statement is perhaps better made in the reverse order, that is, the checking of the supply of moisture induces earlier blooming. In the fields the supply was checked, there being no heavy rains from July 4 to August 16. In the cans, the supply was constant except as noted. With plants 22, 7, and 30 the saturation was changed as shown in the table during each period. Plant No. 7, where the moisture was reduced from 90 percent to 30 percent, produced the maximum number of blooms one week earlier than the average. Plant No. 22 bloomed later than the average due at least in part to the accidental topping of the plant.

Most of the plants were grown in soils where the saturation was kept constant or nearly so, semiweekly weighings being made to show the loss of water and the depreciation below the desired content, after which water was added to bring the saturation to the desired point or a little above. Where the saturation was varied, the change was made when the squares began to form and when the blooming period was nearly over. It will be noted that the plants used large amounts of water during the entire second period and well into the third. On account of the breaking of the balances with which the weighings were made,

no records were obtained after the third week in September. The second period covered nearly the entire blooming period of the plants.

Records similar to those shown in Tables 1 and 2 for 1915 are presented in Tables 3 and 4 for the experiments conducted in 1916.

TABLE 3.—*Liters of water applied weekly from July 25 to October 7, to individual cotton plants grown in potometers in 1916, with the percentage of saturation at which each was maintained.*

Plant No.	Saturation, percent.	Week ending									
		July 25.	Aug. 8.	Aug. 14.	Aug. 22.	Aug. 28.	Sept. 4	Sept. 12.	Sept 19.	Sept. 25.	Oct. 7.
4	45	2.25	9.00	13.50	11.25	13.50	6.75	11.25		6.75	4.50
11	45		6.75	11.25	11.25	13.50	6.75	11.25		9.00	4.50
17	45		2.25	9.00	9.00	13.50	2.25	11.25		9.00	4.50
36	45		4.50	13.50	9.00	13.50	4.50	11.25	2.25	9.00	4.50
12	60	2.25	13.50	18.00	11.25	15.75	11.25	4.50	13.50	11.25	4.50
18	60		13.50	13.50	13.50	9.00	9.00	13.50	6.75	6.75	4.50
41	60		13.50	13.50	15.75	11.25	9.00	15.75		6.75	4.50
43	60	2.25	11.25	9.00	13.50	11.25	9.00	13.50	2.25	6.75	4.50
30	75	9.00	15.75	20.25	9.00	18.00	9.00	9.00		6.75	4.50
31	75		4.50	11.25	9.00	9.00	6.75	2.25	2.25	6.75	4.50
33	75	9.00	9.00	24.75	15.75	11.25	11.25	6.75		6.75	4.50
Totals . . .		24.75	103.50	157.50	128.25	139.50	85.50	49.00	27.00	85.50	49.50

TABLE 4.—*Number of flowers opening weekly on individual cotton plants grown in potometers in 1916, with the number on 10 plants in the field.*

Plant number.	Week ending						
	July 25.	Aug. 8.	Aug. 14.	Aug. 22.	Aug. 28.	Sept. 4.	Sept. 12.
4		1	4	10	8	5	5
11				4	9	11	16
17			3	8	9	5	4
36		3	5	10	8	9	1
12		3	8	15	14	9	
18			1	8	11	7	4
41		2	4	10	7	7	6
43		2	4	8	8	9	2
30		7	5	12	6	3	
31			2	5	2	9	6
33		15	8	16	3		
Total on 11 plants . .		33	44	105	85	74	42
Total on 10 field plants . . .	53	44	85	146	58	37	8

The water record in 1916 was carried a little later than in 1915, and showed a considerable demand by the plant well into the fall months. The greatest amount of water was applied to the plants during the four weeks of August, the highest week being the second. On account of the heavy rainfall on July 15 the field plants did not

bloom earlier than the plants in the cans; the maximum blooming period for both was during the third week in August. Except for No. 11 which was accidentally topped, the plants in the cans were quite regular in their period of blooming.

Most farmers are not satisfied if they have not laid their cotton by so that they are free to go fishing by July 4. If the results here presented are of any value, they indicate that later cultivation than is usually given would be of benefit in conserving soil moisture for the use of the plants during the hot summer weather.

AGRONOMIC AFFAIRS.

OFFICIAL CHANGES.

Because of a change in his official duties and his removal from Washington incident thereto, Mr. P. V. Cardon has resigned as Secretary-Treasurer of the Society, effective March 15. Mr. Lyman Carrier, of the Office of Forage-Crop Investigations, U. S. Department of Agriculture, and a former Treasurer of the Society, has been appointed acting Secretary-Treasurer by President Lyon, and all correspondence regarding memberships and dues should be addressed to him at Washington.

Attention is also called to the changes in the standing committees of the Society, as shown on the back cover page of this number. On the Committee on Soil Classification and Mapping J. G. Mosier and C. A. Mooers have succeeded G. N. Coffey and L. J. Briggs. President Lyon has removed himself as chairman of the Committee on Standardization of Field Experiments and has appointed A. T. Wiancko, a former member of the committee, in his stead; new members on this committee are F. S. Harris and S. C. Salmon, the latter succeeding W. M. Jardine. No changes were made in the Committee on Terminology. On the Committee on Varietal Nomenclature, W. C. Etheridge has succeeded C. G. Williams. The whole-hearted cooperation of the entire membership with these new officers and committeemen is earnestly solicited.

ANNUAL DUES FOR 1918.

Under the by-laws of the Society, the JOURNAL is not to be sent to those who have not paid their dues by April 1. Because of a change in the Secretary-Treasurership and other conditions which have some-

what delayed collections this year, the April number is being sent to all members whose dues for 1917 are paid, as well as all new members for 1918. Before the May number is mailed, however, the payment of dues will be checked and those who are in arrears for 1918 will be taken off the mailing list. If you have not already paid your dues for 1918 and wish to continue to receive the JOURNAL promptly you should remit the amount, $2.50, promptly to the new Secretary-Treasurer, Mr. Lyman Carrier, U. S. Department of Agriculture, Washington, D. C.

MEMBERSHIP CHANGES.

The membership reported in the March issue was 638. Since that time 9 new members have been added, 2 have been reinstated, and 1 has resigned, a net gain of 10 members and a present membership of 648. The names and addresses of the new members and of the two reinstated, the name of the one resigned, and such changes of address as have been noted since the last issue, are as follows:

NEW MEMBERS.

CLEVENGER, C. B., College of Agriculture, Madison, Wis.
GILLIS, M. C., 401 E. Douglas St., Bloomington, Ill.
IBERICO, JUAN R., Yurimaguas, Loreto, Peru, S. A., via Para, Brazil.
LOVE, RUSSELL M., R. F. D. No. 2, Tarentum, Pa.
RUNK, C. R., 250 W. Tenth Ave., Columbus, Ohio.
SMITH, V. C., College of Agriculture, Columbus, Ohio.
VEACH, C. L., College of Agriculture, Athens, Ga.
WATER, E. J., 91 West 11th St., Columbus, Ohio.
YOUNG, PHILIP H., Kans. State Agr. College, Manhattan, Kans.

MEMBERS REINSTATED.

MCCALL, M. A., Lind, Wash.
NEWTON, ROBT., F. Battery, Can. Anti-Aircraft B.E.F., France, via P. M., New York, N. Y.

MEMBER RESIGNED.

SUDDATH, ROBERT O.

CHANGES OF ADDRESS.

BINFORD, E. E., Dadeville, Ala.
BLEDSOE, R. PAGE, Experiment Station, Waterville, Wash.
BRYANT, RAY, Stillwater, Okla.
BURSCH, DAN M., R. F. D. No. 3, Chanute, Kans.
BUSHEY, A. L., Plankinton, S. D.
CARROLL, J. S., Starkville, Miss.
CHAPMAN, JAMES E., 1812 Linden Ave., Baltimore, Md.

DEATRICK, EUGENE, Mont Alto, Pa.
DOUGLAS, J. P., 402 E. Chalmers St., Champaign, Ill.
KEMP, ARNOLD M., Fairmount, Ind.
KENNARD, F. L., Colfax, Wash.
LECHNER, H. J., Court House, Astoria, Ore.
MORRISON, J. D., Elbon, S. Dak.
NASH, C. W., Morris, Minn.
THOMAS, MELVIN, Charleston, Ill.
WALLER, ALLEN G., 2028 F St., NW., Washington, D. C.
WALSTER, H. L., 5520 Blackstone Ave., Chicago, Ill.

Mail for the following members has been returned unclaimed. Any one knowing the present address of any of these members will confer a favor on the Secretary-Treasurer by reporting the information to him.

BLISS, S. W.,
BOARDMAN, W. C.,
FREEMAN, RAY,
HURST, J. B.

ROLL OF HONOR.

In the February JOURNAL a list of those members of the Society who were known to be serving their country in its military forces was published. Since that time, a number of names have been added to the list. The editor will appreciate the favor if those who know of other members of the Society than those noted below who should be added to this list will send their names to him.

SAMUEL D. GRAY,
E. E. GRAHAM,
M. B. GILBERT,
A. D. ELLISON,
JAMES E. CHAPMAN,
H. R. CATES,
A. M. BRUNSON,
B. B. HOLLAND,
O. F. JENSEN,
C. H. KARLSTAD,
P. H. KIME,
LEROY MOOMAW,
J. A. PURINGTON,
J. V. QUIGLEY,
GEO. T. RATLIFFE,
L. C. RAYMOND,
PHIL. E. RICHARDS,
F. J. SCHNEIDERHAN,
W. R. SCHOONOVER,
HERSCHEL SCOTT,
PAUL TABOR.

NOTES AND NEWS.

G. M. Garren is now assistant agronomist in plant breeding at the North Carolina station.

E. J. Holben has been appointed assistant in experimental agronomy at the Pennsylvania station.

R. R. Hudelson, assistant professor of soils in the University of Missouri, is now a first lieutenant of artillery and E. M. McDonald, assistant professor of farm crops in the same institution, is a second lieutenant of infantry in the National Army.

W. M. Jardine, president of the American Society of Agronomy in 1917 and for the past several years dean and director of the Kansas college and station, has been elected president of that institution, succeeding H. J. Waters, who, as previously noted, is now managing editor of the *Kansas City Weekly Star.*

H. G. Knight, for the past several years dean and director of the Wyoming college and station, has been elected to a similar position in Oklahoma and assumed his new duties February 1. He was succeeded in Wyoming by A. D. Faville.

F. G. Merkle, who has been assistant in the department of agronomy in the Massachusetts Agricultural College during the past year, has been made an instructor in the same department.

M. F. Miller, professor of soils in the University of Missouri, has been made assistant dean of the college and assistant director of the station in addition to his other duties.

J. A. Purington, of the Massachusetts college, enlisted in the U. S. army last December. He was on the *Tuscania* when she was sunk by a submarine in February, but was fortunate enough to be numbered among the survivors and at last reports was somewhere in England.

H. N. Vinall has been at Wichita, Kans., for the past two months, supervising purchases of grain sorghum and other seeds for sale to farmers at cost in the drought-stricken regions of Oklahoma and Texas where there was a general failure last year. This work is being done for the Seed Stocks Committee of the U. S. Department of Agriculture.

Meeting of the Ohio Section.

The Columbus (Ohio) Section of the American Society of Agronomy held its second annual meeting on Wednesday afternoon, January 30, 1918, in Townsend Hall, Ohio State University. At this meeting Mr. J. W. Ames, chief chemist of the Ohio Agricultural Experiment Station, discussed "Sulfofication in Relation to Nitrogen Transportation in Soils." Dr. J. F. Lyman, Department of Agricultural Chemistry and Soils of the Ohio State University, discussed "The Food Problem and the War." About 30 men were in attendance at the meeting, and took part in the discussion of these two subjects. The meeting was very profitable and enjoyable. The officers elected for the coming year were: President, Firman E. Bear; and Secretary-Treasurer, Wallace E. Hanger.

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THE EFFECT OF SODIUM NITRATE APPLIED AT DIFFERENT STAGES OF GROWTH ON YIELD, COMPOSITION, AND QUALITY OF WHEAT—2.[1]

J. DAVIDSON AND J. A. LE CLERC.

INTRODUCTION.

In a previous paper[2] were reported the effects of sodium nitrate applied at different stages of growth on the yield of crop, percentage of yellowberry, and protein content of the grain. It was shown that when applied at the first stage, sodium nitrate increased very considerably the yield of the crop, that when applied at the second stage it increased the protein content and "flintiness" of the grain, and that when applied at the third stage it did not have any effect either on the yield of the crop or on the composition and quality of the grain. Attention was called to the new method of plotting used in the experiment. The plots were laid out after the crop was up, each plot showing uniformity of plant growth. This made it possible to limit the size of the plot to one square rod with very satisfactory results. It may be stated in passing that experiments carried out this year in Nebraska fully corroborate our observations made in our experiments conducted last year in Kentucky with reference to the particular effect of nitrogen at the different stages of growth and with

[1] Contribution from the Plant Chemical Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. Presented at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917.

[2] Davidson, J., and Le Clerc, J. A. The effect of sodium nitrate applied at different stages of growth on the yield, composition and quality of wheat. *In* Jour. Amer. Soc. Agron., 9: 145–154. 1917.

reference to adaptability of our new method of plotting for experiments of this kind.

In this paper we want to present and discuss some additional data obtained in our last year's experiments, namely, the effect on the ash, potash, and phosphoric acid content of the grain, and on the nitrogen content of the straw.

Ash, Phosphoric Acid and Potash.

As seen from Table 1, the various treatments in the experiment did not affect the ash, phosphoric acid, or the potash content of the grain in any distinct or concordant manner. The variations in the phosphoric acid are on the whole very slight. Should these small varia-

Table 1.—*Percentage of ash, phosphoric acid, and potash in the grain from plots to which nitrate of soda was applied in various quantities at various stages of growth.*

Fertilizer added at each application.	No. of applications.	Stages of growth.	Percentage of ash.			Percentage of P_2O_5.			Percentage of K_2O.		
			Water applied.		No water applied.	Water applied.		No water applied.	Water applied.		No water applied.
			Fertilizer in solution.	Fertilizer in solid state.		Fertilizer in solution.	Fertilizer in solid state.		Fertilizer in solution.	Fertilizer in solid state.	
2 lbs. $NaNO_3$..	1	First	1.90	1.98	2.05	1.02	.99	1.00	.542	.524	.538
			1.82	1.86	1.97	.93	.92	.96	.527	.522	.533
Do.	1	Second	1.95	1.95	1.98	1.03	1.03	1.04	.551	.559	.552
			1.90	1.92	1.99	.99	.98	1.00	.495	.495	.550
Do.	1	Third	1.86	1.89	1.98	.99	1.03	1.01	.539	.555	.540
			1.94	1.88	2.04	1.00	1.00	1.03	.533	.528	.542
1 lb. $NaNO_3$...	2	First and second	1.9	1.95	1.82	1.00	1.01	.94	.552	.555	.502
			1.88	1.75	1.88	.95	.92	.95	.507	.490	.527
Do.	2	Second and third	1.97	2.01	2.17	1.03	1.01	1.05	.548	.560	.529
			1.91	1.99	2.08	.97	.95	1.04	.487	.483	.545
Do.	2	First and third	1.88	1.85	1.95	.98	1.00	.95	.544	.526	.543
			1.97	1.82	1.83	.97	.90	.91	.508	.478	.493
⅔ lb. $NaNO_3$..	3	First, second and third	2.09	1.91	1.92	1.02	1.02	1.01	.521	.555	525
			1.80	1.92	1.80	.94	.96	.93	.503	.504	.408
2 lbs. $NaNO_3$ + 2 lbs. KCl	1	First	1.57		1.73	.90		.86	.507		.486
			1.91		1.84	.95		1.02	.533		.526
Do.	1	Second	1.78		1.83	.98		.97	.526		.505
			1.98		1.87	1.01		.98	.504		.500
Do.	1	Third	1.77		2.02	.97		.97	.544		.510
			1.93		1.92	.96		1.03	.518		.543
2 lbs. KCl.....	1	First	1.86		2.06	1.00		1.01	.541		.555
			1.95		1.89	1.03		.97	.536		.558
Do.	1	Second	1.78		1.93	.97		.98	.534		.528
			1.91		2.07	.99		.97	.509		.502
Do.	1	Third	1.94		1.84	.98		.95	.549		.513
			1.97		1.89	1.00		1.00	.544		.539
Check			2.04		1.99	1.06		.98	.576		.582
			2.02		1.89	.99		1.04	.524		.529

tions be taken into consideration there is possibly a very slight tendency toward a somewhat higher phosphoric acid content in those cases where the nitrogen was applied in the second stage. It would be useless, however, to speculate whether the nitrogen applied at the first stage caused a depression in the phosphoric acid or whether the nitrogen applied at the second stage stimulated the phosphoric assimilation. Headden[3] found a distinct depression in the phosphoric acid content when sodium nitrate was applied. More experimentation is necessary in order to decide whether the results obtained by Headden are the rule, our results being the exception, or vice versa. It is likely that Headden's results are the rule, as there are certain theoretical considerations which would be in harmony with this substitution of nitrogen for phosphorus. The case would be similar to the substitution of sodium for potassium. We will perhaps be able to throw some light on the question when we are ready to report on the results of our Nebraska experiments. With reference to the ash and the potash content there is no tendency toward any consistency whatever.

Protein Content in Straw.

The term protein with reference to straw represents the total nitrogen multiplied by 6.25. The protein content is given instead of the nitrogen content, both for the sake of uniformity and to accentuate the consistent variations in the nitrogen content. As seen from Table 2 the protein content in the straw follows the same tendency as the protein content in the grain. The straw of the plots which received the sodium nitrate at the second stage shows a distinctly increased protein content, the increase being proportional to the amount received. Of the plots which received their nitrogen in two stages those which received it in the first and second stage, and in the second and the third respectively show an appreciable increase of protein in the straw; those, however, which received it in the first and the third stage do not show such an increase. The same is true about the plots which received the full application in the first and third stages respectively.

The application of potassium chloride depressed very distinctly the protein content of the straw. This observation is in full accordance with the results of Headden, who found that potassium chloride depressed the nitrogen in the plant but not in the grain.[4] From Table

[3] Headden, W. P. A study of Colorado wheat. Colo. Agr. Expt. Sta. Bul. 219.

[4] Loc. cit.

2 it will also be noted that the yield of straw was increased whenever nitrates were added at the first sage. The application of KCl had no effect on the yield, irrespective at what stage the potash salt was applied.

TABLE 2.—*Percentage of protein in straw and weight of straw from plots to which nitrate of soda was applied in various quantities at various stages of growth.*

Fertilizer added at each application.	No applications.	Stages of growth.	Percentage of protein in straw.			Weight of straw, lbs.		
			Water applied.		No water applied.	Water applied.		No water applied.
			Fertilizer in solution.	Fertilizer in solid state.		Fertilizer in solution.	Fertilizer in solid state.	
2 lbs. $NaNO_3$	1	First	4.12	4.47	4.65	22.1	22.8	20.4
			4.74	4.39	4.91	20.2	17.8	19.7
Do.	1	Second	6.69	6.05	6.50	9.5	10.8	9.8
			6.50	5.74	6.62	9.4	9.4	7.4
Do.	1	Third	4.55	4.65	4 30	10.3	9.5	9.8
			4.12	4.43	3.91	8.4	9.1	9.1
1 lb. $NaNO_3$	2	First and second	5.17	5.61	5.44	16.3	15.9	16.3
			4.52	4.78	4.91	17.5	15.7	16.8
Do	2	Second and third	5.41	5.00	6.25	11.0	9.3	9.3
			5.83	5.44	5.48	7.4	8.6	8.2
Do.	2	First and third	3 95	4.47	4.74	17.1	15.5	15.7
			3.77	4.25	4.68	16.1	15.7	15.9
⅔ lb. $NaNO_3$	3	First, second and third	4.65	5.09	5.17	12.7	12.6	14.9
			4.82	4.52	4.47	13.4	13.9	16.4
2 lbs. $NaNO_3$ + 2 lbs. KCl	1	First	4.65		3 77	20.0		19.4
			3.95		4.47	24.6		21.8
Do.	1	Second	6.37		5.44	9.0		9.1
			5.96		5.92	12.0		10.6
Do.	1	Third	4.21		3.68	9.3		7.8
			4.17		3.86	11.2		9.5
2 lbs. KCl	1	First	3.24		3.24	8.8		11.1
			3 69		3.99	10.8		9.2
Do.	1	Second	3.50		3.77	10.5		10.2
			3.82		3.64	11.6		9.6
Do.	1	Third	3.42		3.32	9.1		8.4
			3.64		3.59	9.9		10.0
Check			3.95		4.04	12.4		8.5
			3.86		4.21	9 1		10.9

These results bear out further our conclusion that within the limits of our experiment it is the presence of nitrogen in the soil at the second stage which is responsible for the increase of the protein content in the grain and straw and for prevention of yellowberry in the grain. Headden's[5] work can be interpreted to agree with the results obtained in our experiment. Headden applied his nitrogen at a

[5] Headden, W. P. Yellow berry in wheat, its cause and prevention. Colo. Agr. Expt. Sta. Bul. 205.

period which corresponded to our first stage and obtained a flinty grain high in protein. But the crop in his experiments did not respond in yield to the application of the nitrate, as nitrogen is not the limiting factor in the soils of Fort Collins. The added nitrate was not used up by the plant during the first stage of growth. The local condition further excludes the possibility of the removal of the nitrates by drainage. The added sodium nitrate consequently was present in the soil at the time which corresponds to our second stage of growth. It is the presence of the nitrate at this stage which, in our opinion, prevented yellowberry and produced a high protein content in the experiments of Headden.

Headden[6] comes further to the conclusion, on the basis of his experiments, that flintiness and high protein content are a function of the soil and not of climate. According to the conclusion of Le Clerc and his associates[7] as a result of three years' experiments, climate and not soil played the predominant part in influencing the composition and flintiness of wheat. In reality, however, the results obtained by Headden are not necessarily at variance with the conclusions reached in the Laboratory of Plant Chemistry. Under ordinary field conditions the crops depend for their nitrogen upon nitrification which is favored or hindered to a very considerable extent by climatic conditions. If Headden obtained the same results in a year which was very unfavorable with reference to rainfall as were obtained in a normal year it was probably because in his experiments the crop did not depend upon nitrates produced in the soil during that year, as he added ready-made sodium nitrate.

Summary.

1. No conclusion can be drawn from our experiments with reference to the effect of sodium nitrate on the ash, phosphoric acid, and potash content of the grain.

2. The protein content in the straw showed the same tendencies as the protein content in the grain, i. e., there was an increased protein content as a result of the nitrate applied at the second stage.

3. An increase in the yield of straw as well as of grain was noted whenever nitrates were applied at the first stage.

[6] Headden, W. P. A study of Colorado wheat. Colo. Agr. Expt. Sta. Bul. 219.

[7] Le Clerc, J. A., and Leavitt, S. Trilocal experiments on the influence of environment on the composition of wheat. U. S. Dept. Agr., Bur. Chem. Bul. 128.

Le Clerc, J. A., and Yoder, P. A. Environmental influences on the physical and chemical characteristics of wheat. *In* Jour. Agr. Research, 1: 275. 1914.

4. Potassium chloride depressed the protein content in the straw.

5. Headden's work can be interpreted to agree with the results of our experiments.

6. The results of Headden's experiments as well as our own are not opposed to the conclusion of Le Clerc and his associates that flintiness and high protein content are a function of climate.

Erratum.—In the first paper by these authors, published in Jour. Amer. Soc. Agron., vol. 9, no. 4, on p. 150, Table 1, read "Yield of crop (grain and straw), pounds," instead of "Yield of grain, pounds."

THE DETERMINATION OF MOISTURE IN SOILS.[1]

B. S. Davisson and G. K. Sivaslian.

Introduction.

The method commonly employed for determining moisture in soils is that of direct drying in an air oven heated by various means, as steam, gas, or electricity. A desire to overcome the objectionable features of these methods and to obtain an absolutely dry basis instigated the work reported in this paper. The objections which should be overcome are the long time necessary for removing the moisture, the contamination of the sample by gases from combustion, the oxidation of the organic material due to the long heating at a temperature of 105° to 110° C. in air ovens, and the incomplete removal of all the moisture from the sample.

Historical.

In 1898 Tryller[2] constructed a drying oven in which the heat from the small ring burners passed through a series of spaces in the walls and out at the top. The idea of this construction is to prevent contact between the soils and gases resulting from combustion. The author considered the results obtained by this oven to be sufficiently concordant for accurate work. However, drying for fourteen days at 105° C. and cooling and weighing daily did not yield absolute nor constant results. Often the sample shows an increase in weight after

[1] Contribution from the Laboratory of Soil Technology, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication February 23, 1918.

[2] Tryller ——. Uber die Bestimmung der Trokensubstanz im Torf. *In* Landw. Versuchs., 49: 145. 1898.

it has decreased considerably. The author maintains that drying with his oven is essentially as satisfactory as drying in a vacuum desiccator.

Puchner[3] discusses Tryller's drying oven and admits that it prevents, to a certain extent, the action of gaseous products of combustion. He holds that the irregularity of the results obtained by Tryller are due to the unequal heating of different parts of the oven and the condensation of mositure on the glass and the soil, due to the high hygroscopicity, while transferring the sample to the desiccator. He then carried out some experiments in which he covered the dishes in the oven and left them covered when cooling in the desiccator. Better results were obtained in this way but they were not absolute. Puchner concludes that drying of a soil at 105° C. in such an oven does not give the actual moisture content and that soil analysis based upon such moisture determinations cannot be entirely correct.

Mitscherlich[4] gave some time to accurate moisture determinations in soils and finally recommended drying in a vacuum over phosphorus pentoxide at 100° C. He used individual vacuum desiccators with phosphorus pentoxide for each sample. The desiccator after evacuation was placed in an air oven at the desired temperature. Because of the thickness of the walls of the desiccator it was found that the temperature of 100° C. within the desiccator could be more easily obtained by suspending the vessel in an oven and allowing live steam to come in contact with the walls of the desiccator. Mitscherlich employed wheat starch for studying the drying process because it remained unchanged during the drying. He found that increasing the temperature lessened greatly the time necessary for drying the sample. Four hours' drying was found sufficient to remove all the moisture from the starch or soil sample at 100° C., thus showing that the method gives absolute dryness, the dry substance remaining constant during five to nine hours' further drying. The author calls attention to the error introduced by handling the drying dishes with the bare hands.

König[5] used an electrically heated vacuum desiccator in which he maintained a temperature of 100° C. and used phosphorus pentoxide as the desiccant. The weighings were repeated to constant weight. A comparison of the results obtained by this method and by direct

[3] Puchner, H. The determination of dry matter in soil samples. *In* Landw. Versuchs., 55: 309. 1901.

[4] Mitscherlich, A. Zur Methodik der Bestimmung der Benutzungswarme des Akerbodens. *In* Landw. Jahrb. 31: 578. 1902.

[5] König, J. Relations between the properties of soils and the assimilation of foods by plants. *In* Landw. Versuchs., 66: 415. 1907.

drying at 105° to 110° C. does not show any very marked difference in the amount of moisture obtained upon different soil samples.

Although considerable attention has been given to the subject of moisture determinations in soils, the positive evidence of the superiority of any method is not conclusively established. It must be admitted that direct drying in an air oven does not give absolutely trustworthy results. The drying in a vacuum over phosphorus pentoxide at 100° C. appears to be superior to drying in an air oven. The time necessary for a moisture determination is greatly lessened by the vacuum method.

A comparison of the methods reported seemed necessary to establish fully the method which gives the most reliable results. A comparison of direct drying in gas and electrically heated ovens and in a vacuum over phosphorus pentoxide at 105° C. constitutes the experimental part of this paper.

Experimental.

The gas oven used in this work is the ordinary copper oven provided with a jacket for a liquid bath. Oil was used in this oven and by careful manipulation the temperature was maintained very constant at 105° C. No precaution was taken to prevent the gas fumes from coming in contact with the samples as they were being dried. The oven was used as it is generally in laboratories for drying. The electrically heated oven is one of the common types on the market having a control thermostat. The temperature was kept constant at 105° C. at the shelf on which the samples were placed.

In the first work of drying in a vacuum at 105° C. over phosphorus pentoxide, desiccators were used, but it was found practically impossible to maintain a vacuum in other than a glass desiccator and the glass desiccators which were obtainable would not withstand the temperature. An electrically heated vacuum oven was obtained and was found to be very satisfactory. Trouble was experienced in getting a tight seal between the door and the chamber without the use of some kind of sealing material. For this purpose a mixture was prepared by mixing finely divided graphite and melted beeswax until the mixture became very thick and pasty. After cooling, this material was cut into pencils. A pencil was then drawn around the face of the warm door until a good coating of the contact face was obtained. Upon closing the door this graphite sealed it very tightly and a vacuum could be easily maintained for twenty hours. All dryings were made at 105° C. and about 1.5 cm. pressure. At the end of the drying

period the vacuum was broken slowly and the ingoing air thoroughly scrubbed through concentrated sulfuric acid. The phosphorus pentoxide was placed in a shallow dish on a shelf about 3 inches below the shelf on which the samples were placed.

The samples, 10 grams, were weighed into glass weighing dishes 5 cm. in diameter and 3 cm. deep with ground-glass covers. Larger dishes, 7½ cm. × 3 cm. were compared with the smaller ones and found to be no better for a 10-gram sample. After drying, the dishes were closed and cooled in desiccators over calcium chloride and were weighed. It was found to be bad practice to place many samples in one desiccator because the opening of the desiccator to remove dishes permitted moisture to enter and those dishes remaining longest in the desiccator gave lower values for moisture. It is advisable to use an individual desiccator for each sample when accurate work is desired. In no case should the bare hands be allowed to touch the dishes after being cleansed for the sample.

Cornstarch was used for checking the methods because of its finely divided condition, high hygroscopicity, homogeneity, and its remaining unchanged during the drying process. The employment of such a substance makes it easy to establish if an absolutely dry substance can be obtained. The starch was uniformly mixed and preserved in glass-stoppered bottles.

The data obtained for the moisture content of the starch sample by the vacuum method are reported in Table 1. The total moisture was removed in a period of two hours, when further drying did not yield any change in the moisture content.

TABLE 1.—*Grams of moisture in 10 grams of starch, as shown by drying for different periods in a vacuum oven over P_2O_5 at 105° C.*

Time of drying, hours	Number of determination.					Average.
	1	2	3	4	5	
One	1.2711	1.2638	1.2650	1.2361	1.2603	1.2592
Two	1.2897	1.2938	1.2950	1.2960	1.2950	1.2939
Three	1.2953	1.2962	1.2954	1.2902	1.2889	1.2932
Four	1.2948	1.2914	1.2936	1.2960	1.2915	1.2934

Ten determinations were then made to obtain the probable error of the method. The error calculated by the method of least squares is satisfactorily low and shows that very consistent results can be obtained. The determinations of moisture in grams in 10-gram samples of starch were as follows: 1.2963, 1.2947, 1.2942, 1.2953, 1.2941, 1.2926, 1.2927, 1.2936, 1.2888, and 1.2976, with an average of

1.2939 and a probable error of ± 0.0017, or a percentage error of ± 0.001.

A starch sample was then subjected to drying at the same temperature but no phosphorus pentoxide was used to absorb the moisture. The vacuum pump was kept running all the time. On drying for two hours with this method a new sample of starch gave 1.2804 grams of moisture. The same starch yielded 1.2203 grams of moisture in two hours and 1.2739 grams in 24.5 hours when no phosphorus pentoxide was used. This shows that the moisture can not be removed easily without the use of the pentoxide and the time necessary for drying the sample is lessened greatly when the oxide is used.

Drying in electric and gas ovens was then compared with the vacuum method. The data in Table 2 show the superiority of the vacuum method. The moisture obtained by direct drying is far

TABLE 2.—*Grams of moisture in 10 grams of starch as shown by drying in ovens of various kinds at a uniform temperature of 105° C.*

Kind of oven.	Time of drying, hours.	Number of determination.					Average.
		1	2	3	4	5	
Vacuum, over P_2O_5.....	2.00	1.2817	1.2766	1.2792	1.2816	1.2829	1.2804
Electric.....	16.50	1.2581	1.2534	1.2429	1.2556	1.2323	1.2484
Gas	26.25	1.2213	1.2159	1.2210	1.2195	1.2202	1.2195

below that obtained by the vacuum method. The electric oven gave higher results than the gas oven and the results within themselves are not as concordant as those of the vacuum method. The superiority of the electric oven over the gas oven is shown and for this reason the gas oven was not employed in studying the moisture determinations on soils.

The data obtained for comparison of the electric oven and the vacuum method as applied to soils are found in Table 3. Clay and muck soils were used for this study because they present greater difficulties of moisture determinations than other soils, due to their large amount of surface and high hygroscopicity. The soils were air dried and ground to pass a 20-mesh sieve. Ten-gram samples were used. The data show the superiority of this vacuum method. The electric oven gave results 2.2 percent less for muck and 3.4 percent less for clay than the total moisture found by the vacuum method. It is also shown that 4 hours' drying is sufficient to remove the moisture by the vacuum method, whereas the electric oven did not yield definite results in 10 hours' drying.

TABLE 3.—*Grams of moisture in 10-gram samples of muck and of clay soil, as determined by drying for different periods in a vacuum oven over P_2O_5 and in an electric oven.*

MUCK SOIL.

Kind of oven.	Time of drying, hours.	Number of determination.					Average
		1	2	3	4	5	
Vacuum, over P_2O_5	2.0	1.8762	1.8814	1.8892	1.8806	1.8792	1.8813
Do.	4.0	1.9035	1.9125	1.9016	1.9032	1.8994	1.9040
Do.	7.0	1.9055	1.9148	1.9088	1.9087	1.9022	1.9080
Electric	4.0	1.7764	1.8403	1.8491	1.8332	1.8296	1.8257
Do.	7.0	1.8200	1.8563	1.8612	1.8612	1.8619	1.8538
Do.	10.0	1.8210	1.8533	1.8739	1.8732	1.8856	1.8612

CLAY SOIL.

Vacuum, over P_2O_5	3.0	0.4451	0.4451	0.4412	0.4422	0.4435	0.4434
Do.	5.0	.4471	.4473	.4443	.4525	.4445	.4471
Do.	7.5	.4467	.4473	.4434	.4477	.4425	.4455
Electric	5.0	.4191	.4135	.4293	.4227	.4150	.4199
Do.	8.5	.4211	.4305	.4341	.4234	.4270	.4272
Do.	11.0	.4215	.4355	.4306	.4309	.4278	.4292

The vacuum method produced a dry soil, a condition which can not be obtained by the electric oven on several hours' drying. The danger of oxidation of the organic matter is removed when the vacuum method is employed. The loss of any volatile matter from drying in the vacuum oven will probably not be any greater than the loss which will take place on long drying in the gas or electric oven.

The air-drying oven is not capable of removing all the hygroscopic moisture from a soil sample. Soils having a high hygroscopicity will, therefore, retain considerable moisture under the ordinary procedure of drying and the results obtained will not represent the actual moisture content of the sample.

In order to show that the electric drying oven does not remove all the moisture from a soil sample, a determination was made by taking samples of muck soil and drying for 3½ hours in the vacuum oven over P_2O_5 at 105° C. The dry substance found was 8.0750 and 8.0978 grams for the two samples. These samples were then placed uncovered in a desiccator over 10 percent sulfuric acid and the desiccator evacuated. After standing in this desiccator for 15 hours the samples were removed and dried in the electric oven at 105° C. for 7.5 hours and the dry substance found was 8.1800 and 8.1688 grams. The samples were again placed over 10 percent sulfuric acid in a vacuum and after 15 hours they were dried by the vacuum method for 3.5 hours at 105° C., when the dry substance found was

8.0795 and 8.0938 grams, respectively. The values obtained by the electric oven are considerably higher than those obtained by the first drying of the soil sample by the vacuum method. The oven is, therefore, not capable of removing all the hygroscopic moisture from the soil. The second drying by the vacuum method gave results which are very nearly the same as those obtained by the first drying. This method of drying gives results which are definite and represent the actual moisture content of the soil. Soils having high hygroscopicity offer no difficulty in moisture determinations by the vacuum method, while direct drying fails to remove all the hygroscopic moisture.

Conclusions.

1. Drying of soil samples in gas or electrically heated ovens will not give the true moisture content of the soils.

2. Drying by the vacuum method yields trustworthy and concordant results.

3. Four hours' drying at 105° C. in a vacuum over phosphorus pentoxide is sufficient to remove the moisture from soils having high hygroscopicity.

THE MECHANICAL FACTORS DETERMINING THE SHAPE OF THE WHEAT KERNEL.[1]

SARKIS BOSHNAKIAN.

The shape of the grain of wheat is affected by a number of spikelet characters, which are mainly: (1) The stiffness of the glumes, (2) the size and shape of the space in which the grain develops, (3) the number of grains in the spikelet and their position, (4) the density of the head, (5) the pressure caused by the growth of different parts of the head, and (6) the species which produces the kernel. Just as the interior surface of stone or hard-shelled fruits determines to a very large extent the shape of the enclosed seed, so the character and form of the surroundings of the developing grain of wheat determine the shape of the mature kernel.

An ideal wheat kernel whose free development has not been arrested by coming in contact with the surrounding parts of the spikelet should be symmetrical; that is, when the grain is divided by a plane dorsi-ventrally passing through the crease, the two halves should be alike with the dimensions reversed. Such a grain is shown at *A* in figure 27. The position in the spikelet of uniformly developed kernels is seen in figure 27 *E*. Symmetrical grains are very rarely found in nature.

The types of kernel most frequently found are those shown in *B* and *C* of figure 27; their relative positions on the spikelet are shown in *Fb* and *Fc* respectively. In these cases the plane does not divide the grain into symmetrical halves. Grain *B* dorsally viewed is flattened on the left side, while in the case of *C* the opposite side is flattened. This flattening occurs always on the side of the kernel which is nearer to the rachis, as shown in *F*. It is evident then that all grains which are flattened on the left side are produced by the florets on the left side of the spikelets, and those flattened on the right side are borne on the opposite side of the spikelet. This character, which is constant for all species, enables one to determine the side of the spikelet on which different kernels were produced.

[1] Received for publication November 6, 1917.

All species of wheat do not produce this type of flattening in the same degree. In *Triticum vulgare,* although easily noticed, it is not so pronounced. The writer's observations of the various forms show that they rank about as follows with respect to their degree of flattening:

1. *Triticum vulgare;*
2. *T. capitatum;*
3. *T. compactum;*
4. *T. polonicum;*
5. *T. turgidum;*
6. *Triticum durum;*
7. *T. spelta;*
8. *T. dicoccoides;*
9. *T. dicoccum;*
10. *T. monococcum.*

In durums the degree of flattening varies with different varieties.

The extent to which flattening takes place depends primarily upon the stiffness and shape of the outer glumes; the stiffer the glumes

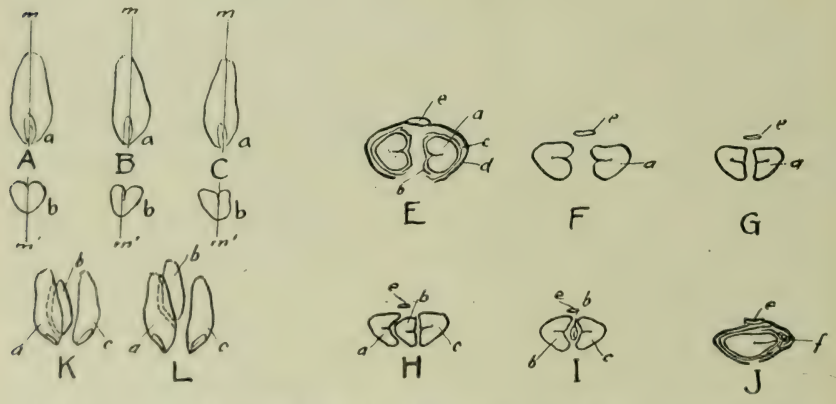

FIG. 27.—Types of wheat kernels. *Aa*, symmetrical grain; *Ab*, cross section (*m-m'*, axis). *Ba*, asymmetrical grain produced on left side of spikelet, left side of kernel flattened; *Bb*, cross section. *Ca*, asymmetrical grain borne on right side of spikelet, flattened on right side; *Cb*, cross section. *E*, cross section of spikelet showing position of well-developed symmetrical kernels; *a*, grain; *b*, palea; *c*, fertile glume; *d*, outer glume; *e*, rachis. *F*, position of grains with rounded cheeks, glumes not shown; note flattening of side of rachis, *e*. *G*, grains growing close together, showing flat cheeks. *H*, spikelet with the kernels tightly held together, showing effect of central spikelet *b* on the shape of the cheeks of the lateral kernels *a* and *c*; flattening of cheeks, as in *G*, taking place when grains *b* and *c* face ventrally, depression of crease taking place when the lateral kernel *a* faces the dorsal portion of the central kernel *b*. *I*, sterile or partially developed central floret producing slight depressions along the crease of the lateral florets *b* and *c*. *J*, spikelet of *T. monococcum* showing grain with protruded cheeks; *e*, rachis; *f*, sterile floret. *K* and *L*, effect of position of central grain *b* on the depression of crease of lateral grain *a*. *K*, depression on lower part of grain *a*. *L*, depression on upper portion of grain *a*.

the more tightly the grains are pressed toward the rachis. On the side of the rachis the grain does not have sufficient room for development and therefore does not fill up as fully on this side as it does on the other. The ranking shown above is in reality a ranking of the species according to the stiffness of their outer glumes.

The cheeks of the grain are the visible parts on each side of the crease when the kernel is viewed ventrally. The cheeks may be round and plump (*F*), flat (*G*), sunken with sharp edges (*I*), or protruded (*J*). The cheeks are filled, plump, and round (*E* and *F*) when the spikelet is soft and spreading, and contains not more than three grains. This type of a roomy spikelet will be found among the *vulgare* and squareheads, and in some of the clubs. The flattening of the cheeks (*G*) takes place when there are two kernels which face each other in the spikelet and when the latter is stiff and tends to press these two kernels together. The flattening of the cheeks in this case is mechanical.

The reader should be reminded that the grain of wheat throughout its period of development is very soft and that it hardens only after it attains its maximum development. Hardening is a drying process and occurs during the last few days of its period of maturation. As the kernel is very soft before this period, the slightest pressure on the grain through contact is very apt to modify its shape.

The process of the flattening of the cheeks of the wheat grain is not different from the flattening of the sides of the horse-chestnut. It will be remembered that when only one chestnut is developed from a flower it has more or less rounded sides; when, however, the flower produces two chestnuts the sides which face each other are flattened out instead of being rounded as in the first instance. We find the same phenomenon in maize. In well-fertilized ears the four sides of the kernels are flat, while in poorly fertilized ears where an isolated pair of kernels are found the sides of the grains which face are flat while the sides which do not come into contact remain rounded. This principle of flattening in this and in many other cases is due to pressure resulting through contact. Flat cheeks will be found as a rule among the 2-grained and tight-glumed species such as the wild wheat, the emmers, and most of the spelts.

When three grains are present (*I*) and the texture and form of the glumes are as in the previous case the cheeks of some of the kernels of the basal florets tend to sink or flatten, depending on the size and position of the seeds developing between the two basal grains. If the central grain is small (*Ib*), the cheeks of the large

kernels on both sides (*Ia* and *Ic*) of this tend to sink to fit the outline of the central grain (*Ib*). If on the other hand the middle grain is fairly large (*Hb*), usually the grains whose ventral sides face one another (*Hb* and *Hc*) are flattened ventrally more or less while the other outer grain (*Ha*), which faces the dorsal portion of the central kernel (*Hb*), develops a depression along the crease and the edges of the cheek become sharp. The presence of sterile florets in the center will produce a slight depression along the ventral surface.

The position of the central grain or grains will determine the region where the depression is to occur. If the small central grain (*Kb*) is located along the middle portion of the crease of the outer kernel (*Ka*) the depression occurs along that region. If it has a higher position (*Lb*) the upper portion of the cheek only will be depressed (*La*). Grains of this third type occur particularly among spelts and often in durums and English wheats.

The fourth and last case is that of the *monococcum,* whose spikelets almost always produce but one kernel. If the glumes were not stiff and did not press the grain inside tightly against the rachis the shape of the normally developed grain might approach that of the *vulgare.* On account of the pressure along the sides of the grain the latter naturally flattens, and since there is no other grain in the same spikelet which by contact will arrest the growth of the cheeks the latter keep on protruding until the grain attains its full size (*J*).

That considerable pressure is exerted by the glumes may be demonstrated by the presence of parallel vein marks on the sides of the grain of *monococcum,* especially that facing the rachis. The parallel sunken lines are the exact reproductions of the veins of the lemma that envelops the grain. The vein marks of the glumes could not have been impressed on the plastic grain without pressure and contact. Such vein impressions are also occasionally seen on the kernels of the spelts.

The shape of the kernel of the club wheats is often different from that of the others. The grains of this form are short and in some cases almost spheroid, depending of course upon the variety. The shortness of the grain is caused by the presence of a genetic factor or factors which shortens a number of size characters such as length of glumes, awns, internodes, culm, and kernel. This is not a physical factor.

In club wheats we find, besides shortness, an irregularity as regards the shape of the grain. Kernels obtained from the central portion of the head of most of the clubs are fairly symmetrical and

uniform, but those taken from the upper portion of the head, especially of squareheaded clubs, are irregular and often flattened somewhat like those of *Triticum monococcum*. This is due to the close and dense arrangement of the spikelets one above the other. When the internodes are short the spikelets spread out and arrange themselves almost at right angles with the rachis one above the other. Under such conditions the development of a kernel is checked through the growth of competing grains in spikelets above and below it. The pressure developed from growth acts along a direction perpendicular to the plane of symmetry of the kernel and tends to flatten out the cheeks. The irregularities are produced by pressure as well as by the crowding of the grain on the sides, above, and below each developing grain.

There are other mechanical causes affecting the shape of the grain; though mechanical they are not due to pressure. Irregularities on the surface of the grain are to a great extent the result of evaporation of the moisture in the grain. We have soft and hard grains with numerous intermediate gradations. Soft or starchy grains have almost always rounded cheeks; whereas those which are hard or corneous shrivel to some extent upon drying and consequently produce irregularities on the surface of the grain. This phenomenon is comparable with the smoothness of the surface of the soft starchy and the wrinkled surface of the sweet or dent corn.

The mechanical causes determining the shape of the grain should not be confused with the purely genetic factors which are to some extent responsible for the production of certain grain forms. Reference has already been made to the genetic causes affecting size of the kernels of dense wheats. The shortness of the grain of the club and the unusual length of that of the Polish wheat are not the results of any form of mechanical pressure but are already determined before the embryo begins to develop. The grain will remain short or grow long depending upon the species and the length factor which the plant carries.

There are many grain characters which are the result of both genetic and mechanical factors. It was said at the beginning of the discussion that the shape of the grain was primarily dependent upon the shape and stiffness of the glumes. The shape of the glumes varies with different species, and the grain whose shape is to a great extent dependent on that of the glumes varies also depending upon the species. The first cause in this case is genetic, but its result on the grain is mechanical. Most of the forms considered in this paper belong to the latter category.

LOSS OF ORGANIC MATTER IN CLOVER RETURNED TO THE SOIL.[1]

GEORGE E. BOLTZ.[2]

INTRODUCTION.

The practice of applying organic matter is generally considered more or less essential in maintaining and increasing the fertility of certain soils. The value of such soil treatment is supposed to be derived largely from the beneficial effects of the organic matter as well as the fertilizing elements incidentally carried by it. In many instances the fertilizing elements are considered only of secondary importance, while it is assumed that the organic matter in crops and manures is the chief factor which causes the increased productiveness of soils.

It is often advocated in agricultural literature that the most efficient method of maintaining or increasing the supply of organic matter in the soil is by the use of green manures and crop residues. This method is given preference over that of feeding the crop and returning the manure to the soil, because a large percentage of the organic matter is destroyed in passing through the animal. With clover this loss represents about 66 percent of the total organic matter present in the crop. By incorporating the green crop directly in the soil or by cutting and allowing it to remain on the surface for some time before plowing under, it is assumed that this loss is greatly reduced if not entirely avoided.

In order to obtain information regarding the loss of organic matter from a clover crop used for green manuring as compared with the loss when fed to farm animals and returned to the soil in the form of manure, experiments were conducted at the Ohio Agricultural Experiment Station with the results here given.

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[2] The author wishes to acknowledge the many useful suggestions made and the aid rendered during the course of this investigation by C. G. Williams, agronomist, and J. W. Ames and C. J. Schollenberger, chemist and assistant chemist, all of the Ohio station.

PLAN OF EXPERIMENT 1915–1916.

A plot of soil having an area of 18 square feet was treated with green clover at the rate of 7,744 pounds per acre, to correspond to the practice of mowing a crop and allowing it to remain on the surface of the ground for some time before plowing it under. A similar area was treated with a like quantity of clover, which was spaded under. A similar experiment was conducted in a lysimeter test, each container having an area of 9 square feet and receiving an application of green clover at the rate of 17,520 pounds per acre. The loss on ignition of the moisture-free soil and clover was determined on samples taken at the beginning and end of the experiment, and the loss of organic matter calculated from these data. The clover was applied to the soil October 12, 1915, and the residue collected and soil sampled on May 5, 1916, so that the clover was exposed to the

TABLE 1.—*Organic matter retained in soil at the end of 206 days and percentage lost from clover left on surface as compared with that spaded into the soil, 1915–16.*

Method of application	Clover applied.	Residue on surface at end of experiment.	Organic matter.			
			Applied.	In residue at end of experiment.	Retained by soil.	Loss.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Percent.*
Clover on surface.						
Field test	2,000	639.2	1,075.4	360.9	4.1	66.05
Lysimeter test	2,000	440.1	1,202.8	302.5	76.0	68.52
Clover mixed with soil.						
Field test	2,000		1,075.4		769.4	28.45
Lysimeter test	2,000		1,202.8		498.8	58.53

action of the weather for a period of 206 days. The figures in Table 1 express the loss of organic matter during the experiment of 1915–16 in a ton of green clover when applied at the rate indicated above.

PLAN OF EXPERIMENT 1916–1917.

Two sets of duplicate plots, adjacent to each other and each measuring 6 by 3 feet, were spaded to a depth of 6 inches; during the spading, 1,573 grams (3.46 pounds avoirdupois) of dried and finely cut clover were thoroughly and evenly mixed with the soil of each of two plots, while the same quantity of uncut clover was spread upon the surface of each of two others, the soil having been compacted after spading. This quantity on an area of 18 square feet corresponds to 8,000 pounds or 4 tons of dry clover to the acre. Samples of both the clover used and of the soil from each plot before

adding the clover were taken and subsequently analyzed. The plots were prepared as described on November 8, 1916, and were immediately covered with a wire screen in order to prevent the clover spread on the surface from being blown away, as well as to prevent other material from being carried on to the plots. The duration of the experiment was 187 days, from November 8, 1916, to May 4, 1917, when the plots were sampled in the same manner as at first, after carefully removing the residue of clover from the surface of the two plots on which it had been spread.

The first experiment was intended to furnish data on the loss of organic matter only; in order to make the results of the second experiment of greater value, carbon and nitrogen determinations on the different samples were made instead of the determination of loss on ignition.

Analyses were made of the soil from each plot, both at the beginning and at the end of the experiment. The clover applied and the residue removed were also analyzed. The percentages of carbon and of nitrogen in the soil at the beginning and at the end of the experiment are shown in Table 2, while Table 3 gives data on the carbon

TABLE 2.—*Percentage of carbon and of nitrogen in soil to which 8,000 pounds of dry clover to the acre was added on the surface and by spading in, at the beginning and at the end of a period of 187 days.*

Element and time of determination.	Clover spaded in.			Clover spread on surface.		
	Plot 1.	Plot 3.	Average.	Plot 2.	Plot 4.	Average.
Carbon:						
At beginning	1.058	1.021	1.039	1.021	1.087	1.054
At end	1.148	1.169	1.158	1.064	1.041	1.052
Nitrogen:						
At beginning	.097	.097	.097	.097	.097	.097
At end	.105	.105	.105	.099	.100	.099

and nitrogen in pounds per acre. The clover added contained 42.31 percent of carbon and 1.99 percent of nitrogen. From Plot 2 6,164 pounds of residue were removed, containing 29.34 percent of carbon and 1.91 percent of nitrogen, while from the corresponding Plot 4 7,568 pounds of residue were removed, containing 23 percent of carbon and 1.38 percent of nitrogen.

RESULTS OF EXPERIMENTS.

There was very little if any loss of nitrogen during the experiment, either from the clover incorporated or left on top of the soil. Owing to the small increase in percentage of total nitrogen produced

in the soil by the clover added and to the difficulty of securing a representative sample as well as the limitations of the method for total nitrogen in soils, the slight differences shown in the table of the nitrogen recovered are well within the limits of analytical error.

TABLE 3.—*Pounds per acre of carbon and of nitrogen in soil to which 8,000 pounds of dry clover to the acre was added on the surface and by spading in, with loss from the clover at the end of 187 days.*

CARBON.

Determination.	Clover spaded in.			Clover spread on surface.		
	Plot 1.	Plot 3.	Average.	Plot 2.	Plot 4.	Average.
At beginning	19,785	19,093	19,439	19,093	20,327	19,710
Added in clover	3,385	3,385	3,385	3,385	3,385	3,385
Total	23,170	22,478	22,824	22,478	23,712	23,095
At end	21,468	21,860	21,664	19,897	19,467	19,682
Loss during period	1,702	618	1,160	2,581	4,245	3,413
Remaining in residue				1,809	1,741	1,775
Net loss	1,702	618	1,160	772	2,504	1,638

NITROGEN.

At beginning	1,814	1,814	1,814	1,814	1,814	1,814
Added in clover	159	159	159	159	159	159
Total	1,973	1,973	1,973	1,973	1,973	1,973
At end	1,964	1,964	1,964	1,851	1,870	1,860
Loss during period	9	9	9	122	103	113
Remaining in residue				118	104	112
Net loss	9	9	9	4	[a]1	1

[a] Apparent gain.

However, the indications are that no appreciable loss of nitrogen occurred.

The data in Table 1 show that the organic matter in a ton of green clover when cut and allowed to remain on the surface of the soil for 206 days decreased from 1,075 pounds originally present to 361 pounds. Of the 715 pounds of organic matter that disappeared from the surface a mere trace, 4 pounds, was retained by the soil, while 711 pounds were lost through processes of decay. The rate of application and the stage of maturity of the clover used in the lysimeter test were different from those used in the field test, but the percentage loss is practically the same in both cases, being 66.05 percent for the field test and 68.52 for the lysimeter test.

The loss of carbonaceous matter expressed as elementary carbon was greater when the clover was allowed to lie upon the surface than when turned under in both the 1915–1916 and 1916–1917 experiments. The average loss shown by the two plots of 1916–1917 with

the clover on the surface was 48.38 percent, while those with the clover incorporated in the soil lost 34.26 percent of the carbon applied during the same experiment. The results of the 1916–1917 experiment are similar to those obtained in 1915–1916. Differences in season and duration of experiment would undoubtedly affect the results.

Value of Green Manures.

Green-manure crops assimilate, concentrate, and return to the soil essential plant nutrition elements that are available for succeeding crops. The fertilizing elements thus prepared for assimilation by other crops may have a beneficial influence after the greater portion of the organic matter by which they are carried is destroyed. Half or more of the organic matter in a crop, depending upon the method employed in returning it to the soil, may be destroyed within six months, yet the beneficial effects are apparent for several years afterward. That mineral fertilizers have a decided value in crop production, whether accompanied by organic matter or not, can not be disputed. Consequently, the value of the fertility elements in a green-manure crop should not be ignored, although they originally came from the soil. Crops having high fertility value should be returned to the soil for their fertilizing constituents as well as for any theoretical value of the organic matter.

Advantage of Feeding Crop and Applying Manure.

Data reported in Ohio station Bulletin 183 from an experiment in which 28 steers were fed on a cement floor, the duration and season of the experiment corresponding very closely to the plot experiments under discussion, indicate that almost exactly one third of the total organic matter in the feed and straw used for bedding was recovered in the manure. This experiment shows that practically as much organic matter is applied to the soil when a crop of clover is fed and the manure applied to the soil as when the crop is allowed to remain on the surface of the ground from fall until spring before being plowed under.

Eliminating the comparatively small amount of fertilizing elements lost in metabolic processes when feeding clover to farm animals and considering the organic matter only, very little would appear to be gained by plowing a clover crop under rather than feeding it and applying the manure.

MILLING AND BAKING TESTS OF EINKORN, EMMER, SPELT, AND POLISH WHEAT.[1]

J. A. LE CLERC, L. H. BAILEY, AND H. L. WESSLING.

Wheats are classified according to Hackel as follows:

Triticum monococcum—Einkorn or one-kerneled wheat.
Triticum sativum dicoccum—Emmer.
Triticum sativum spelta—Spelt.
Triticum sativum tenax vulgare—Common wheat.
Triticum sativum tenax durum—Durum wheat.
Triticum polonicum—Polish wheat.

The einkorn used in our investigations (C. I. No. 2433) was a small grain irregular in size which did not separate readily from the chaff. It seemed much like an immature and shriveled sample of ordinary wheat. Some of the grains were so small that they contained very little endosperm.

The kernels of the emmer (Black Winter, C. I. No. 2337) which was used in this experiment were larger than ordinary wheat and in shape resembled somewhat the rye grain. It was also difficult to remove the chaff from the grain.

The sample of spelt[2] (Alstroum, C. I. No. 3264) resembled emmer quite closely in appearance of the grain; in fact, the names are sometimes confused in this country. Spelt and emmer are both used mostly as stock feed and very little for human food.

The sample of Polish wheat used was obtained from C. B. West, Sheridan, Wyo. The kernels of this sample were even larger than those of durum wheat and about twice as long as those of ordinary wheat. In appearance the kernels were flinty and of an amber color, thus resembling durum wheat. Polish wheat differs from the einkorn and spelt in that it is readily separated from the chaff, so that ordinary thrashing is all that is required to prepare the grain for the miller.

[1] Contribution from the Laboratory of Plant Chemistry of the Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C. Received for publication April 3, 1918.

[2] The three wheats (einkorn, emmer, and spelt) were obtained for us through the courtesy of the Office of Cereal Investigations, Bureau of Plant Industry. The emmer and spelt were supplied hull free. The sample of einkorn was hulled in the laboratory before milling.

Of the wheats, *Triticum sativum tenax vulgare* is the usual source of flour for bread and biscuits. Durum wheat is especially adapted for the manufacture of semolina used in making macaroni. The other wheats have seldom been used in the manufacture of flour. Emmer is sometimes used as a breakfast food.

The object of this experiment was to determine whether these rarer wheats could be successfully milled into good flour and whether the flours produced therefrom would make good bread. Samples of all of these wheats were milled on an Allis-Chalmers experimental flour mill, a sample of hard spring wheat being likewise milled at the same time as a check. All the samples were tempered to 13 percent of moisture over night, then scoured and tempered to 15 percent for 2 hours, and then milled so as to obtain a 65 percent patent flour. No attempt was made to obtain a straight grade of flour or to obtain a maximum flour yield.

The results of milling showed that Polish wheat and emmer have a smaller amount of bran than hard spring wheats, thus indicating a possibly larger flour yield. Even when milled on a 65 percent patent basis all of these flours (except that from spring wheat) were somewhat gray in color, although the flour from spelt was only slightly darker than that from spring wheat.

Table 1 shows the composition of the flours and gives the characteristics of the breads produced therefrom.

From this table it will be seen that flour made from spelt is more nearly like that from spring wheat in its ash, nitrogen, acidity and

TABLE 1.—*Composition of flours and characteristics of bread made from einkorn, emmer, spelt, and Polish wheat.*

Character.	Hard spring wheat.	Einkorn.	Emmer.	Spelt.	Polish wheat.
COMPOSITION OF FLOURS.					
Moisture, percent	11.750	10.450	11.200	11.010	10.300
Ash, percent	0.393	0.811	0.783	0.555	0.848
Protein (N x 5.7), percent	10.090	15.500	13.790	12.250	13.050
Acidity, percent	0.075	0.223	0.213	0.151	0.325
Gluten, wet, percent	27.100	37.700	44.800	31.700	34.500
Gluten, dry, percent	9.900	14.000	14.600	11.000	12.600
Absorption, percent	69.500	66.500	82.000	67.000	76.000
Maximum expansion of dough, c.c.	780	320	680	680	640
CHARACTERISTICS OF BREADS.					
Color, percent	97.5 c.[1]	y. brown	94 c.g.[2]	96 c.g.	95 g.
Texture, percent	98	96	95	96	94
Elasticity, percent	99.5	92	98	98.5	99

[1] c = creamy. [2] g = gray.

gluten content than the other flours. Flour from einkorn, emmer, and Polish wheat are very high in ash, acidity, and in gluten. Emmer flour showed an extremely high absorption capacity, while Polish-wheat flour was second in this respect. Flours from spelt and einkorn had approximately the same absorption as that possessed by spring-wheat flour.

When these flours were baked into bread, the bread made from the einkorn was the least desirable not only in volume but in color, elasticity, and in taste or flavor. In fact, the results obtained with einkorn might indicate that this kind of wheat is not suited to make a good yeast-risen bread. That made from emmer was somewhat better, although not equal to bread made from spring-wheat flour in color, volume, and elasticity. The Polish-wheat bread had a better color than the emmer bread, but the volume was not quite so large. The crumb, however, seemed more moist than that from other breads and in fact this bread had an elasticity almost equal to that of spring-wheat bread. The spelt bread on the other hand compared favorably in most respects to the ordinary wheat bread, except that the color was a little darker. There was no difference in taste and appearance from ordinary wheat bread.

Summary.

1. The rarer wheats, emmer and spelt (both free of hulls) and Polish wheat, can be milled into a satisfactory flour and the flour used in baking a good loaf of bread.

2. The results obtained from einkorn (free of hulls) are not so encouraging.

3. Alstroum spelt seems particularly adapted to the production of a good flour for baking purposes.

4. Black Winter emmer flour has a very high absorption capacity.

5. In view of the well-known present deficiency in our wheat supply the use of emmer, spelt, and Polish wheat as human food (bread, breakfast cereals, etc.) should be encouraged wherever they are available. As they are not superior to the more common varieties of wheat there would be no advantage in having them replace ordinary wheats in normal times.

COMPARATIVE SMUT RESISTANCE OF WASHINGTON WHEATS.[1]

E. F. GAINES.

DAMAGE CAUSED BY STINKING SMUT IN THE NORTHWEST.

Washington, Oregon, and Idaho produce over 40,000,000 bushels of winter wheat annually. Stinking smut is more prevalent in the winter-wheat sections of these States than anywhere else in the United States, and probably a larger percentage of the crop is affected than on an equal acreage anywhere else in the world. It is not uncommon to find whole fields with 40 percent of smut. Several county agents in the more important winter-wheat growing counties have estimated that these three States lose in the neighborhood of 15 percent of their winter wheat by smut. This would mean a loss of 6,000,000 bushels, which are worth, at present prices, over $10,000,000. The prevalence of smut in winter wheat seems to be increasing in spite of the most careful methods of seed treatment. This condition is causing many farmers to abandon winter wheat until some measures can be found to control smut. The elimination of winter wheat is undesirable from the standpoint of distribution of labor in seeding and harvesting and from the fact that winter wheat produces from 1 to 5 bushels per acre more than spring wheat.

PRESENT METHODS OF SMUT CONTROL.

Several methods of producing winter wheat with little or no smut are known. It has been found both by experiment and by farm practice that little or no smut is produced when the crop is seeded very early in the season, but this is not desirable on account of overdevelopment in the fall and a consequent reduction in yield. Moreover, in a dry season or when the cultivation has not been the best, the moisture in the soil in July or early August is insufficient to germinate the seed. It is impossible to sow early except on summer fallow. There is also the added expense of carrying over the seed from the previous year's crop.

Little or no smut is produced in fields that are sown abnormally

[1] Contribution from the Washington Agricultural Experiment Station, Pullman, Wash. Received for publication April 1, 1918.

late, but the weather between Thanksgiving and Christmas is so unsettled that it is often impossible to seed during this period. There is also danger of the grain freezing out when it is sown so late. Therefore, both very early and very late seeding, although eliminating smut to a large degree, may be dismissed as undesirable as a general practice. Winter wheat is normally seeded during the months of September and October in the Northwest. This has been shown by repeated experiments to be the period of maximum infection. It has been suggested that by replowing the summer fallow just prior to seeding, the wind-borne smut spores would be buried beyond the infection zone of the germinating grain and a reduction in smut would result even when the sowing was done in the normal season. This practice is untenable because the expense is prohibitive and the time is not available at this season of the year. Moreover, it leaves the soil in bad physical condition.

As none of the methods of smut control mentioned above are generally practicable, it was thought that, if a variety of wheat could be found that was immune or highly resistant to the attacks of this fungus, it would help in the elimination of this evil.

Investigation on Resistance: Method and Material.

For the past four years the Washington station has been studying the comparative smut resistance of the most common winter wheats of the Northwest. The method employed was to blacken the seed with smut spores just before planting, and sow all the varieties on the same date, under uniform conditions, in rows 18 inches apart. A furrow was made with a small garden push plow, the seed spaced 5 to 7 inches apart therein, and covered with the same implement by plowing in the earth from each side. Enough cultivation was given to keep down weeds in spring and early summer. At harvest time each variety was pulled as it became ripe. The plants were divided into three piles as follows: Plants smut free, plants all smutted, and plants partly smutted. The number of plants in each pile was recorded, then the plants partly smutted were further divided into healthy heads and smutted heads and the number of each recorded. When a head was found that was only partially smutted, if it was more than half smutted it was put into the smutted pile; otherwise it went into the uninfected pile. Table 1 gives the sum of these counts during the past three years.

Table 1 gives the total infection distribution in tabular form of thirteen varieties during 1915, 1916 and 1917. The plantings were

TABLE 1.—*Number of plants smut free, all smutted, and partly smutted under conditions of maximum infection in 1915, 1916, and 1917, with the number of uninfected and smutted heads and the average number of heads produced by the partly smutted plants.*

Variety.	Number of plants.			Number of heads on partly smutted plants.		
	Smut free.	All smutted.	Partly smutted.	Not smutted.	Smutted.	Average total number per plant.
Turkey	810	1	298	7,518	514	26.9
Alaska	35	0	8	101	17	14.7
Fortyfold	118	77	305	1,732	4,452	20 3
Red Russian	85	115	320	1,863	5,754	23.8
Salzer's Marvel	10	15	122	1,069	2,744	31.3
Triplet	77	266	539	2,591	10,690	24.6
Winter Bluestem	25	149	196	949	3,217	21.3
Little Club	50	304	54	233	997	22.8
Jones Winter Fife	49	575	217	910	2,842	17.3
Hybrid 143	43	496	127	606	2,323	23.1
Hybrid 123	17	244	214	630	4,081	19.1
Hybrid 108	41	497	105	490	1,798	21.8
Hybrid 128	43	696	139	565	2,467	21.8

made on November 7, October 14, and November 24, respectively. While this is later than winter wheat is usually seeded, yet the results should be comparable, for all varieties received exactly the same treatment. The large number of heads per plant is not unusual considering the cultivation they received and the fact that each plant had a space of approximately 108 square inches. Counts from an average of 575 plants of each variety or a total of 7,481 plants, of which 2,644 partly smutted plants were divided into 19,257 wheat heads and 41,896 smut heads, are given in Table 1 as the basis of the percentage comparison presented in Table 2.

This compilation has been made in order to show in easily comparable form, the susceptibility to smut of the different varieties of winter wheat. The first column, percentage of infected plants, is the sum of the plants all smutted and partly smutted in terms of percentage of the total number of plants. The third column, total percentage of smut produced, is the sum of the smut produced on both the plants partly smutted and wholly smutted. The fourth column is the percentage of smut produced in an entirely different experiment. It is based on a head count of part of one drill row in each plot of the field variety tests and is the average percentage of smutted heads produced during the last three years from treated grain. This column represents the percentage of smut produced in winter wheat under conditions as unfavorable for smut production as we are able to make them in field practice. This column was put

TABLE 2.—*Percentage of infected plants, percentage of smut on infected plants, and total percentage of loss from smut under conditions of maximum infection, together with the total loss from smut under conditions of minimum infection.*

Variety.	Infected plants.	Smutted heads on infected plants.	Total smut produced.	Smut heads in field variety test.
	Percent.	*Percent.*	*Percent.*	*Percent.*
Turkey	26.96	6.71	1.81	1.8
Alaska	18.60	14.41	2.69	
Fortyfold	76.40	77.64	59.32	3.9
Red Russian	83.65	82.01	68.61	3.9
Salzer's Marvel	93.20	75.04	69.93	
Triplet	91.27	86.93	79.34	2.5
Winter Bluestem	93.24	87.07	81.19	5.6
Little Club	87.75	97.15	85.14	8.1
Jones Winter Fife	94.17	93.36	87.92	4.7
Hybrid 143	93.54	95.79	89.60	9.4
Hybrid 123	96.42	93.28	89.94	8.5
Hybrid 108	93.62	96.27	90.12	6.7
Hybrid 128	95.10	96.90	92.15	8.6

in to show that careful seed treatment and crop rotation do not eliminate smut, although it is less than is produced by the average farmer on summer fallow, according to the estimates of county agricultural agents.

Turkey (Wash. No. 326) is the only highly resistant wheat of commercial importance in the list. Even after a plant was infected 93.29 percent of the normal yield of wheat was produced. In contrast with this, Red Russian, the variety most commonly grown in the moister sections of the State, produced only 17.99 percent of the normal yield after it was once infected. Moreover, only 26.96 percent of the Turkey plants were infected, while 83.66 percent of the Red Russian plants showed infection. Little Club and Jones Winter Fife are much less resistant even than Red Russian. It will be noted that 87.75 percent of the plants of Little Club were infected and that these produced only 2.85 percent of the normal yield of grain. Jones Winter Fife had a higher percentage of infection (94.17 percent), but more grain was recovered from the infected plants (6.65 percent). The same phenomenon is shown with Turkey and Alaska, the two distinctly resistant strains. Turkey has 8.36 percent more infected plants, but recovers 7.7 percent more grain from the infection than does Alaska.

FACTORS CAUSING VARYING DEGREES OF RESISTANCE.

From these irregularities it would seem probable that there are two distinct factors that control the resistance of wheat to smut. One prevents infection, as is seen by the large variation in percent-

age of infected plants between Alaska and Hybrid 123. The other prevents smut-balls from forming, as is seen by the large variation in quantity of wheat produced on infected plants of Turkey and Little Club. If these two factors exist, one preventing infection and one preventing the smut from fruiting after infection, there is a high degree of correlation between them, for in general low percentage of infection is followed with a low percentage of smut-balls produced on the infected plants. The converse is also true. High percentage of infection is associated with a high percentage of smut produced on the infected plants.

Little is known concerning the actual process of infection. The assumption that all infected plants would produce at least one smut-ball may be wrong. We have no means of determining this point. Perhaps many infection threads must enter the host cells and there fuse in order to live and reproduce smut spores at harvest time. It may be, as Kirchner[2] suggests, that a cell sap of slightly higher acid content is associated with a high degree of smut resistance.

Whatever the reason, there is a very marked difference in the resistance to smut of some of the different varieties tested. Under conditions of maximum infection Turkey was reduced in yield 1.8 percent by smut, while hybrid 128 was reduced 92.15 percent under the same conditions.

AGRONOMIC AFFAIRS.

MEMBERSHIP CHANGES.

The membership reported in the April issue was 648. Since that time 6 new members have been added, 4 have resigned, and 1 has died, a net gain of 1 and a present membership of 649. The names and addresses of the new members, names of those resigned and deceased, and such changes of address as have been reported are as follows. A list is also appended of those whose addresses are unknown to the Secretary-Treasurer, recent letters sent to them at the latest reported addresses having been returned unclaimed. Any one who can furnish complete addresses of any of these persons will confer a favor on the Secretary-Treasurer if they will make this information available to him.

[2] von Kirchner, O. *In* Zeitschr. Pflanzenkrank. 26: 17-25. Stuttgart, Apr. 22, 1916. *Reviewed in* Internat. Rev. Sci. Pract. Agr., vol. 7, July, 1916.

NEW MEMBERS.

BUENAVENTURA, LINEA RUEDA, 97 Antiguo Entre 8 y 10, Vedado, Habana, Cuba.
COOPER, M. L., Merryville, La.
COWLES, HENRY C., University of Chicago, Chicago, Ill.
GARBER, R. J., University Farm, St. Paul, Minn.
JOHNSON, T. C., Va. Truck Station, Norfolk, Va.
KIRK, N. M., Bureau of Soils, Washington, D. C.

MEMBERS RESIGNED.

BELL, N. ERIC, LATHROP, E. C., MILES, FRANK C., PACKARD, W. E.

MEMBER DECEASED.

ANDERSON, A. C.

CHANGES OF ADDRESS.

JONES, J. W., Biggs Rice Field Station, Biggs, Cal.
KRALL, J. A., County Agent, Manchester, Iowa.
MOORE, HARVEY L., c-o Thos. S. Newell, R. D., Pemberton, N. J.

ADDRESSES UNKNOWN.

BRUCE, O. C., DOUGLAS, J. P., KENT, W. A., CURREY, HIRAM M., FREEMAN, RAY, KENWORTHY, CHESTER, SHINN, E. H.

ROLL OF HONOR.

Since the last issue, the names of several members of the Society who are serving their country in its military forces have been reported. The complete list reported to date is published herewith. The editor will appreciate the favor if those who know of other members of the Society whose names should be added will report them to him, as well as items of interest regarding any of these men.

BRUNSON, A. M.,
BURNETT, GROVER,
CATES, H. R.,
CHAPMAN, JAMES E.,
CHILDS, R. R.,
DOWNS, E. E.,
ELLISON, A. D.,
GILBERT, M. B.,
GRAHAM, E. E.,
GRAY, SAMUEL D.,
HEAD, A. F.,
HOLLAND, B. B.,
JENSEN, O. F.,
KARLSTAD, C. H.,
KIME, P. H.,
MOOMAW, LEROY,
PALMER, H. WAYNE,
PURINGTON, J. A.,
TOWLE, R. S.
QUIGLEY, J. V.,
RATLIFFE, GEO. T.,
RAYMOND, L. C.,
RICHARDS, PHIL E.,
SCHNEIDERHAN, F. J.,
SCHOONOVER, W. R.,
SCOTT, HERSCHEL,
SMITH, JOHN B.,
TABOR, PAUL,

NOTES AND NEWS.

Carleton R. Ball, for the past several years in charge of work with wheat in the western half of the United States in the Office of Cereal Investigations, has succeeded M. A. Carleton as chief of that office.

Recent changes in the Office of Dry-Land Agriculture, U. S. Department of Agriculture, involve the transfer of J. M. Stephens, superintendent of the Judith Basin Substation, Moccasin, Mont., to the superintendency of the Northern Great Plains Field Station, Mandan, N. Dak., *vice* W. A. Peterson. P. V. Cardon, formerly of the Office of Cotton Investigations, has succeeded Mr. Stephens at Moccasin.

Four field representatives of the Office of Cereal Investigations, U. S. Department of Agriculture, resigned recently to engage in farming on their own account. With their former positions, they are E. L. Adams, superintendent of the Biggs Rice Field Station, Biggs, Cal.; L. R. Briethaupt, superintendent of the field station at Burns, Oregon; N. C. Donaldson, of the Judith Basin Substation, Moccasin, Mont.; and J. D. Morrison, of the Highmore substation, Highmore, S. Dak. Mr. Adams has been succeeded at Biggs by J. W. Jones, former superintendent of the Nephi (Utah) substation, who in turn has been succeeded by A. F. Bracken. J. H. Martin, formerly of the Bellefourche Experiment Farm, Newell, S. Dak., is the new superintendent at Burns, Ore.

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THE TRIANGLE SYSTEM FOR FERTILIZER EXPERIMENTS.[1]

OSWALD SCHREINER and J. J. SKINNER.

INTRODUCTION.

Fertilizer experimentation for determining the specific needs of any particular soil type or crop is one of the big problems before American agriculturists. It is not our purpose here to dwell upon the shortcomings of many efforts in this direction, but we must say in passing that the popular conception, even among agricultural specialists, that this problem can be solved by a soil, or a plant, or an ash analysis is a vain hope which has not and cannot be realized. Much can be learned from such work, but not the fertilizer requirement of the soil or plant to increase the yield, quality, appearance, or freedom from disease. Experimentation direct with soil and plant have thus far been the only means to give this answer and in this connection the soil has nearly always been ignored and the fertilizer combinations tested have always been so restricted that a full and complete answer to this complicated question is yet to be reached. There have been some excellent fertilizer experiments, especially the long-term systems at several of the experiment stations, but by far the greater number of tests made from time to time on this land or that land, this crop or that crop, the country over, have been so lacking in plan and in thoroughness that they have served only a temporary purpose. How-

[1] Contribution from the Office of Soil Fertility Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. Presented by the senior author, with illustrations, at the tenth annual meeting of the American Society of Agronomy, Washington, D. C., November 13, 1917 Received for publication April 3, 1918.

ever useful they may have been, they offer little for the interpretation of the broad fundamental questions of soil fertilization and crop needs. It is not our purpose to disparage the many well-planned experiments which are in successful operation. Rather, we wish to call to the attention of those planning further work, a system of fertilizer experimentation which, with proper and careful attention to soil differences as far as they can be mapped in advance or in the course of the experiment, ought to give a sufficiently comprehensive basis for proper interpretation and easy presentation and handling of the results.

In the following discussion the triangle system is outlined as we have used it in our problems and as others have employed it in similar or related lines, largely as a suggestion to other workers who may not as yet have seen its advantages.

When it is desired to test the effect of all possible ratios of the fertilizer elements, P_2O_5, NH_3, and K_2O, the triangle system has been found to be admirably suited. Graded in 10 percent stages there are in this experiment 66 tests, or graded in 20 percent stages there are 21 tests, involving the fertilizer elements singly, in combinations of two, and in combinations of three.

To bear in mind these various ratios and the results obtained therewith is difficult. In so comprehensive an experiment as this the material must be reduced to a workable basis so that the various phases of the results can readily be presented and the proper correlations and comparisons made.

Use of the Triangular Diagram.

A triangular diagram is shown in figure 28. It is an equilateral triangle in which the extreme points of the angles represent 100 per-cent[2] respectively, of the constituents, P_2O_5, NH_3, and K_2O, as shown in the diagram. Each side of the triangle is divided into ten equal parts and lines are drawn connecting these points.[3]

In the diagram, for the sake of ready reference, the intersections of these lines have been numbered. If we consider the line representing the base of the triangle, it is obvious that the point which represents 100 percent K_2O (56 in the diagram) represents at the same time 0 percent NH_3, and the point which represents 100 percent NH_3

[2] The term "100 percent," as here used, refers to the maximum quantity of a single fertilizer constituent chosen for the experiment.

[3] Such diagrams for physical-chemical work, giving still finer rulings, namely, 100 to each line, can be purchased from the Cornell Cooperative Society, Ithaca, N. Y.

(66) likewise represents 0 percent K_2O. If we take a point half way between these two points (61) we have a mixture of the two salts in equal proportions; i. e., a mixture of the salts represented by that point will be 50 percent K_2O and 50 percent NH_3. Similarly, point 16 represents 50 percent K_2O and 50 percent P_2O_5, and point 21 represents 50 percent NH_3 and 50 percent P_2O_5.

If we take a point nearer to either of the corners, we will have a higher percentage of one and a correspondingly lower percentage of the other. For instance, at point 59 the composition is 70 percent K_2O and 30 percent NH_3; at 29 it is likewise 70 percent K_2O, but 30 percent P_2O_5; at 64 it is 20 percent K_2O and 80 percent NH_3; at 45 it is likewise 80 percent NH_3 but 20 percent P_2O_5.

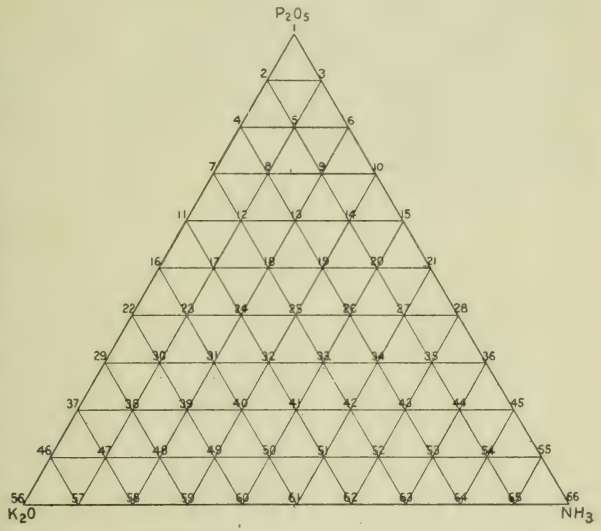

FIG. 28. Triangular diagram with the points numbered, representing the 66 fertilizer combinations in 10 percent stages.

As stated above, points on the base line 56–66 represent mixtures containing no P_2O_5. The next line above this, namely 46–55, represents mixtures containing throughout 10 percent P_2O_5, but varying amounts of the other two constituents. Similarly the line 37–45 represents throughout 20 percent mixtures of P_2O_5; line 29–36, 30 percent mixtures of P_2O_5, and so on upward until point 1, the apex of the triangle, is reached, where the composition is 100 percent P_2O_5 as already explained. Similarly, points on the line 1–66 represent 0 percent K_2O; line 2–65 represents 10 percent K_2O but varying amounts of P_2O_5 and NH_3, and so on until at point 56 the composition is 100 percent K_2O. Likewise points on the line 1–56 represent 0 percent NH_3; line 3–57 represents 10 percent NH_3, but varying amounts of P_2O_5 and K_2O, and so on until at point 66 the composition is 100 percent NH_3. It is therefore obvious that any point

within the triangle represents a 100 percent mixture composed of three constituents, its position in the triangle being determined by the composition. For instance, point 12, being on the 60 percent phosphate line represents that composition of P_2O_5, namely 60 percent, and being at the same time on the 10 percent NH_3 line and the 30 percent K_2O line it represents 10 percent and 30 percent of these constituents respectively. The composition of the mixture represented by this point is therefore P_2O_5 60 percent, NH_3 10 percent, and K_2O 30 percent, i. e., the composition of the fertilizer mixture is 60–10–30. Similarly the point 34 represents a mixture of the composition P_2O_5 30 percent, NH_3 50 percent, K_2O 20 percent, or a fertilizer composition of 30–50–20.

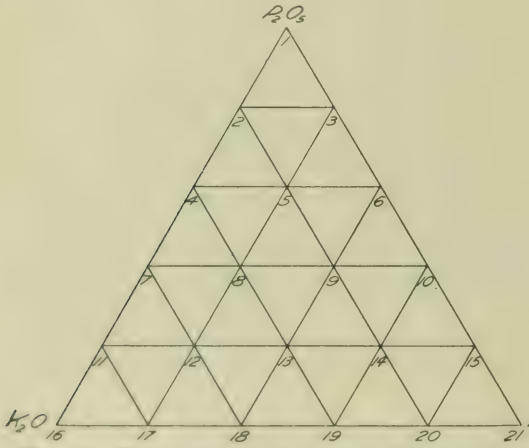

FIG. 29. Triangular diagram with the points numbered, representing the 21 fertilizer combinations in 20 percent stages.

It is of course evident that any other percentage composition or ratio of fertilizers could likewise be represented on such a diagram. Commercial brands can be represented on such a diagram by reducing the sum of the commercial percents to a basis of 100, thus an 8–4–4 fertilizer becomes 50–25–25. This point lies halfway between 18 and 19. Similarly a 10–2–2 fertilizer becomes 72–14–14 and lies between 8 and 9 on the diagram. For accurately locating such points, the finely ruled and subdivided paper referred to in the footnote should be used.

In stating the percentage composition of the fertilizer mixtures in such work, the figures are always given in the order—P_2O_5, NH_3, and K_2O as shown above. The symbols P_2O_5, NH_3, and K_2O are used in conformity with fertilizer practice, even when the nitrogen, for instance, is in the nitrate form.

The triangle therefore represents single fertilizer constituents at the apices or vertices, mixtures of any two constituents along the

boundary lines of the triangle, and mixtures of all three constituents within the triangle.

In Table 1 is given the composition represented by each of the 66 points in the diagram.

TABLE 1.—*Sixty-six possible ratios of the three fertilizer constituents, P_2O_5, NH_3, and K_2O in 10-percent stages.*

Point No.	Ratio or percentage composition.			Point No.	Ratio or percentage composition.			Point No.	Ratio or percentage composition.		
	P_2O_5.	NH_3.	K_2O.		P_2O_5.	NH_3.	K_2O.		P_2O_5.	NH_3.	K_2O.
1	100	0	0	23	40	10	50	45	20	80	0
2	90	0	10	24	40	20	40	46	10	0	90
3	90	10	0	25	40	30	30	47	10	10	80
4	80	0	20	26	40	40	20	48	10	20	70
5	80	10	10	27	40	50	10	49	10	30	60
6	80	20	0	28	40	60	0	50	10	40	50
7	70	0	30	29	30	0	70	51	10	50	40
8	70	10	20	30	30	10	60	52	10	60	30
9	70	20	10	31	30	20	50	53	10	70	20
10	70	30	0	32	30	30	40	54	10	80	10
11	60	0	40	33	30	40	30	55	10	90	0
12	60	10	30	34	30	50	20	56	0	0	100
13	60	20	20	35	30	60	10	57	0	10	90
14	60	30	10	36	30	70	0	58	0	20	80
15	60	40	0	37	20	0	80	59	0	30	70
16	50	0	50	38	20	10	70	60	0	40	60
17	50	10	40	39	20	20	60	61	0	50	50
18	50	20	30	40	20	30	50	62	0	60	40
19	50	30	20	41	20	40	40	63	0	70	30
20	50	40	10	42	20	50	30	64	0	80	20
21	50	50	0	43	20	60	20	65	0	90	10
22	40	0	60	44	20	70	10	66	0	100	0

In Plate 5 the composition of the 66 ratios varying in 10-percent stages are shown as circles with red, black, and white segments to represent visually the proportions of P_2O_5, NH_3, and K_2O.

PREPARATION OF THE FERTILIZER MIXTURES VARYING IN 10-PERCENT STAGES.

In order to make clear the manner of preparing fertilizer mixtures for such an experiment, let us assume that a test of acid phosphate, sodium nitrate, and potassium chloride is to be made, that the plats are to be 100 square feet, and that the fertilizers are to be applied at the rate of 50 pounds per acre of the active fertilizer constituents. This means that the sum total of P_2O_5, NH_3, and K_2O will be in all cases 50 pounds per acre. As the size of the plats in these experiments is 100 square feet, it becomes necessary to calculate the quantity of each fertilizer required in the total of 66 fertilizer combinations so as to obtain the proper quantity and proper ratio for each plat.

Suitable containers are used for holding these fertilizer combinations until required for use in the field. These are numbered from 1 to 66, corresponding with the numbers of the plats in the experiment. These containers, for a small experiment like this, are set in the form of a triangle, as shown in the diagram of Plate 5. The addition of the respective analyzed fertilizer substances is thus made as follows:

Acid phosphate.—If the acid phosphate analyzed 14.0 percent P_2O_5 and the application is to be at the rate of 50 pounds of P_2O_5 per acre, then 357.15 pounds of the acid phosphate will be required. For a plat of 100 square feet, 0.8175 pound or 370.3 grams will be required. This, then, is the quantity to be put into container No. 1. The next row of containers, Nos. 2 and 3, is to have only 90 percent of this quantity (45 lbs. P_2O_5 per acre), namely, 333.3 grams. The next row of containers is to have only 80 percent of the full quantity (40 lbs. P_2O_5 per acre), namely, 296.2 grams. This gradation of the quantity of acid phosphate which is to be weighed out and put into the respective containers is best shown by the figures in Table 2.

TABLE 2.—*Grams of acid phosphate (14 percent P_2O_5) required in different fertilizer mixtures.*

Fertilizer container along line in Plate 5.	Quantity of acid phosphate, 14 percent P_2O_5.	Fertilizer container along line in Plate 5.	Quantity of acid phosphate, 14 percent P_2O_5.
	Grams.		*Grams.*
1	370.3	22–28	148.1
2–3	333.3	29–36	111.1
4–6	296.2	37–45	74.1
7–10	259.3	46–55	37.0
11–15	222.2	55–66	none

Sodium nitrate.—If the sodium nitrate analyzes 16.3 percent NH_3,

TABLE 3.—*Grams of sodium nitrate (16.3 percent NH_3) required in different fertilizer mixtures.*

Fertilizer container along line in Plate 5.	Quantity of sodium nitrate, 16.3 percent NH_3.	Fertilizer container along line in Plate 5.	Quantity of sodium nitrate, 16.3 percent NH_3.
	Grams.		*Grams.*
66	319.0	15–60	127.6
55–65	287.1	10–59	95.7
45–64	255.2	6–58	63.8
36–63	223.3	3–57	31.9
28–62	191.4	1–56	none.
21–61	159.5		

306.7 pounds will be required to have 50 pounds NH_3 per acre. For the plat of 100 square feet this will be 0.7041 pound or 319.0 grams. Container No. 66 will therefore receive this full quantity. Containers Nos. 55 and 65 receive only 90 percent of this, 287.1 grams, and so on for other lines of containers according to the figures in Table 3.

TABLE 4.—*Grams of potassium chloride (51 percent K_2O) required in different fertilizer mixtures.*

Fertilizer container along line in Plate 5.	Quantity of potassium chloride 51 percent K_2O.	Fertilizer container along line in Plate 5.	Quantity of potassium chloride 51 percent K_2O.
	Grams.		*Grams.*
56	101.9	11–62	40.8
46–57	91.7	7–63	30.6
37–58	81.5	4–64	20.4
29–59	71.3	2–65	10.2
22–60	61.1	1–66	none.
16–61	50.9		

Potassium chloride.—If the potassium chloride analyzed 51 percent K_2O, then 98 pounds of chloride are required for an application of 50 pounds of K_2O. For the plat of 100 square feet this is 0.2249 pound or 101.9 grams. The various containers will receive the quantities specified in Table 4.

TABLE 5.—*Quantity of fertilizers to be applied per acre at the rate of 100 pounds of the sum of P_2O_5, NH_3, and K_2O, in 20-percent stages.*

Fertilizer No.	Pounds of acid phosphate, 16 percent P_2O_5.	Pounds of sodium nitrate, 19 percent NH_3.	Pounds of potassium sulfate, 50 percent K_2O.
1	625	0	0
2	500	0	40
3	500	105	0
4	375	0	80
5	375	105	40
6	375	210	0
7	250	0	120
8	250	105	80
9	250	210	40
10	250	316	0
11	125	0	160
12	125	105	120
13	125	210	80
14	125	316	40
15	125	421	0
16	0	0	200
17	0	105	160
18	0	210	120
19	0	316	80
20	0	421	40
21	0	526	0

Preparation of the Fertilizer Mixtures Varying in 20-Percent Stages.

For larger experiments in the field a smaller number of plats may be considered more practical. For this purpose the variations are placed at 20 percent, as shown in figure 29. Otherwise the system is the same as that described for the 10-percent stages. The manner of preparing the fertilizer mixtures and the character of the container naturally varies with the size of the plats to be treated. Table 5 shows these 21 mixtures based on the usual composition of the commercial fertilizer material used. A similar table is readily constructed for any other analysis. The table is put on an acre basis; if the plat is one-tenth acre in size, one-tenth of the quantity is taken; if one-twentieth, one-twentieth of the quantity is taken, etc. The table is likewise based on an application of 100 pounds of the active fertilizer constituents. If 50 pounds are to be applied half of the quantity is taken, if 200 pounds is to be applied, twice the quantity in the table is taken, and so on.

The Triangle System in Nutrient Solution Studies.

In nutrient solution work the triangle has been found to be very useful, and it was in the successful prosecution of this work that the system originated.[4] The experiments comprised the 66 cultures mentioned, using the pure, soluble salts $CaH_4(PO_4)_2$, $NaNO_3$, and K_2SO_4 in the proportions required by the system and with a total concentration in each culture of 80 parts per million of P_2O_5, NH_3, and K_2O. Figure 30 represents the green weight of wheat plants in grams obtained in such an experiment, recorded at the proper place in the diagram according to the nutrient solution in which it was grown. This is shown to illustrate the orderly and concise way in which the 66 different experiments are unified and presented to the experimenter for intelligent interpretation. A graphic representation of the numbers in figure 30 is given in figure 31. In this diagram the area of the circle is proportional to the numbers of figure 30 and is made by finding the radius corresponding to these numbers as areas of a circle according to the formula: $A=\frac{R^2\pi}{4}$ for which R can either be calculated or taken from a table of such values to be found in many books. Notice how the numerous results present the story of the experiment as a whole, the relative values of the individual salts, the relative values of the two constituents as shown by the outlines of the triangle, and

[4] Schreiner, Oswald, and Skinner, J. J. Ratio of phosphate, nitrate, and potassium on absorption and growth. *In* Bot. Gaz., 50: 1–30. 1910.

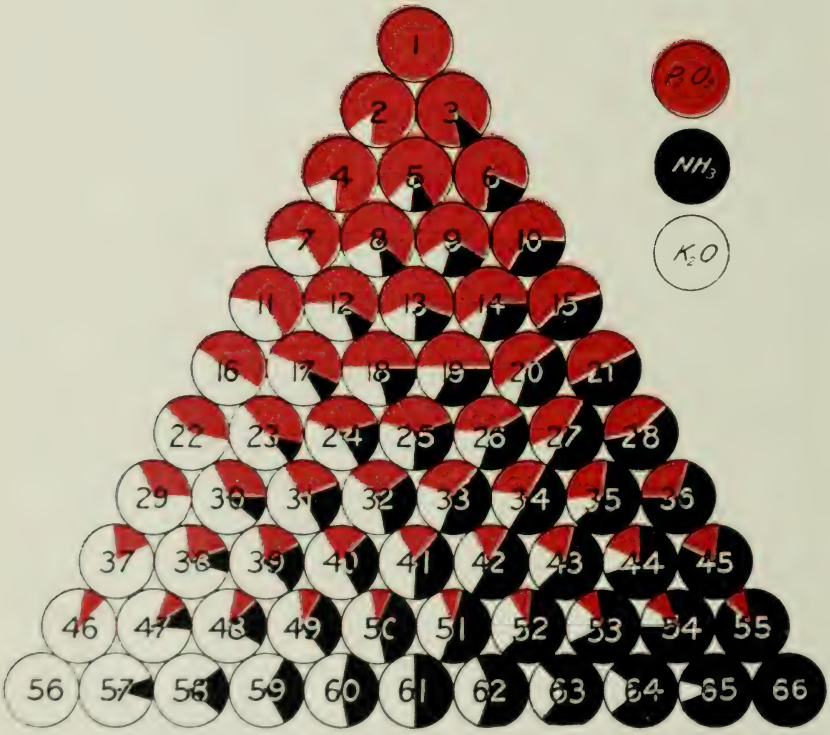

Plate 5. Triangular diagram showing the 66 fertilizer mixtures in 10 percent stages of variation, as indicated by the colors, black, white and red.

the relative values of the three constituents combined. Within the latter group it is at once apparent that the largest growth is in the middle of the lower half of the triangle as a whole. This is the region of greatest growth and these are the culture solutions in which the ratios are best suited for plant development.

A still further illustration of the usefulness of such a diagram becomes apparent when the composition of the crop grown, the ash constituents, protein content, starch content, or any other analytical figure

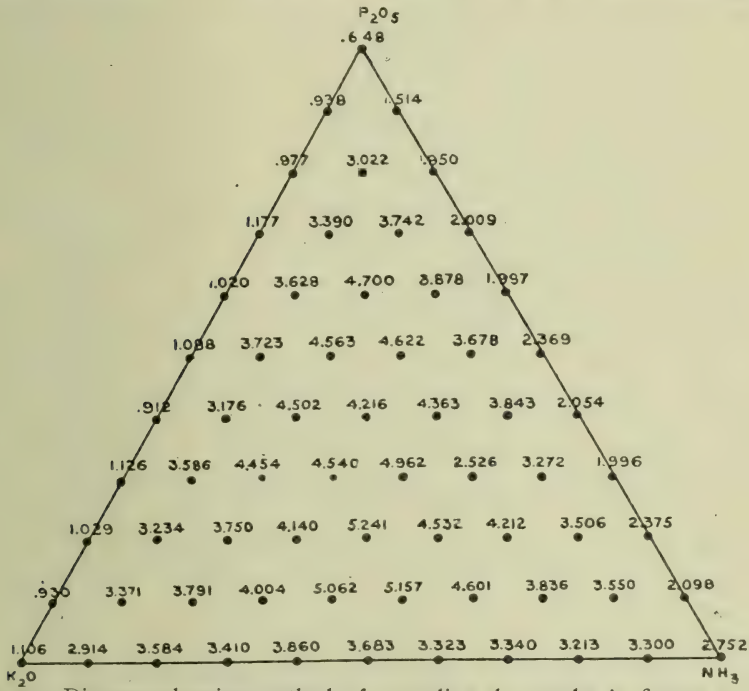

FIG. 30. Diagram showing method of recording the results in figures at the proper place on the diagram. Wheat in solution culture.

such as alkaloidal content, etc., is considered in relation to fertilizer practice or influence. For instance, in the above nutrient culture experiment, the 66 ratios of P_2O_5, NH_3, and K_2O were analyzed after the plants had grown in them for a period of days so as to determine the changes which had taken place in the ratio of the constituents and thus arrive at the ratio which the plants had absorbed. For the three constituents this amounted to 198 determinations and with the original 198 figures and the 198 figures giving the absorbed constituents make a total of 594 individual figures. To obtain a clear conception of what was going on by an interpretation of the analytical results

would tax the mind of anyone to distraction. Here the triangular diagram serves a useful and necessary purpose. In figure 32 the black dots give the original composition in P_2O_5, NH_3, and K_2O, the small circles the composition of the solution after growth, the arrow points the composition of nutrients removed by the growing plant. Notice the unity presented by this representation of these multitudinous and otherwise unintelligible results. The arrows all point to a definite region, that is, the plants, no matter in what solution they were growing, at least attempted to get the composition best suited for their development and this lies in the middle of the triangle, corresponding with the area of greatest growth shown in figures 30 and 31.

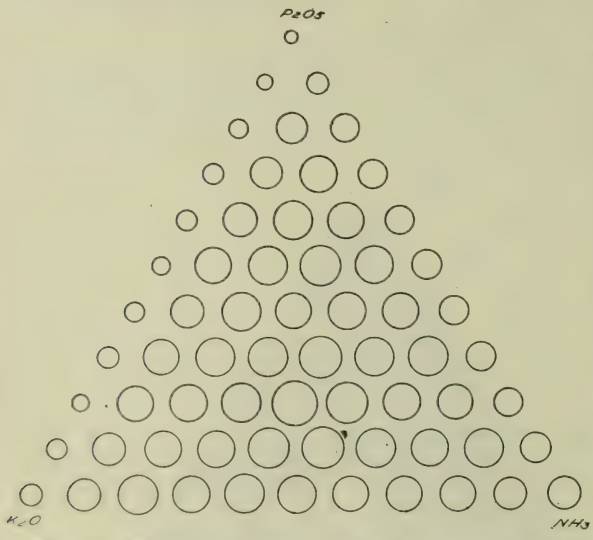

FIG. 31. Diagram showing method of recording the results diagrammatically as areas of circles at the proper points in the diagram same as figure 30. The largest circles indicate the regions of greatest growth.

In our experiments, as is well known, the principal purpose was a study of the influence of certain toxic organic compounds on the growth and on nutrition. For this purpose a second set of 66 cultures is treated with a certain definite quantity of the substance in each culture, and comparison with the corresponding normal culture is then made. In this way the influence of the substance on character and extent of growth, and influence of the fertilizer in overcoming toxicity, is then studied. Such influence is shown in figure 33, wherein the area of greatest growth is shown diagrammatically as it occurred under the influence of different toxic substances, shifting this from the normal in one direction or the other.[5] The significant fact is that

[5] Schreiner, Oswald, and Skinner, J. J. Some effects of a harmful organic soil constituent. *In* Bot. Gaz., 50: 161–181. 1910.

Schreiner, Oswald, and Skinner, J. J. The toxic action of organic compounds as modified by fertilizer salts. *In* Bot. Gaz., 54: 31–48. 1912.

while the region of greatest growth in the case of cumarin is displaced toward the higher phosphate region of the triangle, this is also the fertilizer constituent which more than any other is antitoxic to cumarin; similarly, potash appears antitoxic to quinone and nitrate to vanillin.

These characteristics are brought out by a system of grouping the individual culture results, according to those which contain, for in-

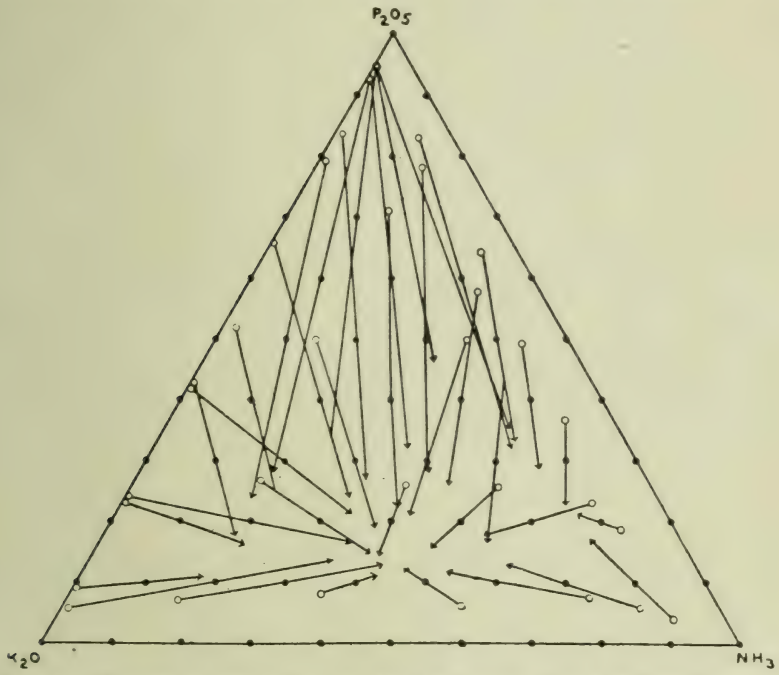

FIG. 32. Diagram showing the ratio of the original, the final, and the ratio of the loss of P_2O_5, NH_3, and K_2O from the culture solution. The dots indicate the ratio of the constituents in the original solution; the circles show the ratio of the constituents in the solution after growth; and the arrows show the ratio of the decrease.

stance, more than 50 percent phosphate, or more than 50 percent nitrate, or more than 50 percent potash, as shown respectively by the dotted lines in figure 34, where the results for cumarin are presented. The cultures included as mainly phosphatic are best seen by reference to figure 28 or plate 5. They are those comprised in the sub-triangle 1–16–21. Similarly, the mainly nitrogenous are those included in the sub-triangle 66–21–61, and the mainly potassic those included in the sub-triangle 56–61–16. From figure 34 it is apparent that in the

mainly phosphatic cultures the cumarin is without effect or that the phosphate has had an antitoxic affect.

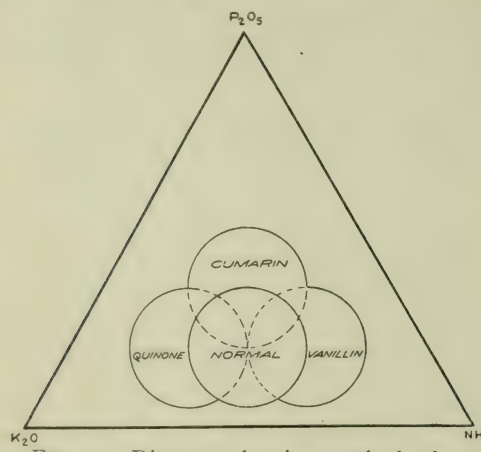

FIG. 33. Diagram showing method of representing the region of greatest growth under different conditions.

There is still another way of handling the data which confirms conclusions reached in this manner, or brings out new relationships and that is to add up the cultures along lines and obtain an average result for each line. For instance, in figure 35, the bottom line contains no phosphate, while the next lines contain consecutively 10, 20, 30, 40, 50, 60, 70, 80, 90 percents and 100 percent phosphate. The relative growths along these various phosphate lines in the case of cumarin arrange themselves in an orderly fashion with increase in phosphate.

Harris[6] has used our triangular system in studying the effect of alkali salts on the germination and the growth of plants. Harris used the salts in 25-percent stages as shown in figure 36, which is taken from his article. Besides the combination sodium-chloride-sulfate-carbonate he used a number of other salts and combinations. The use

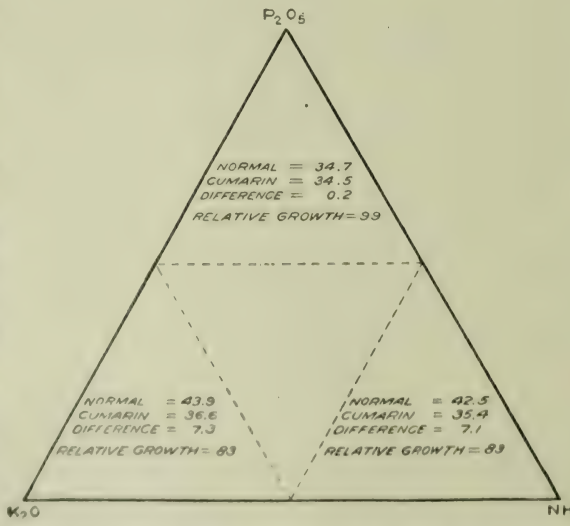

FIG. 34. Diagram showing the method of grouping cultures according to the prevailing fertilizer element.

[6] Harris, F. S. Effect of alkali salts in soils on the germination and growth of crops. *In* Jour. Agr. Research, v. 5, no. 1, p. 1–53. 1915.

of the system in 25-percent stages has one rather serious drawback in certain work on account of the fact that the combinations of all three constituents together are rather limited, in fact confined to three cultures. For the purpose used this may have been permissible, but for a fertilizer or nutrition study these 25-percent variations, in our opinion, are not as suitable as the 20-percent stages, which give six combinations containing the three constituents. Figure 36 illustrates the composition of the solutions of salt mixtures by shading instead of by colors as in Plate 5.

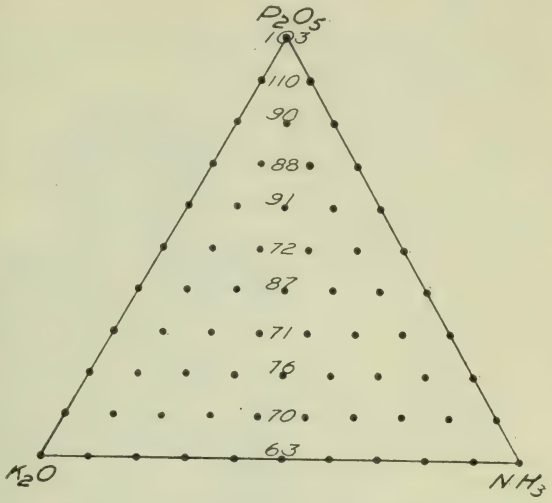

FIG. 35. Diagram showing the method of grouping according to lines of cultures containing a constant amount of any one fertilizer element. Shows the influence of phosphate in overcoming the toxic effect of cumarin.

Harris further used the diagram in representing his results in a way which is worthy of further consideration and is shown in figure 37, taken from his article. He represents his cultures by small circles arranged in the triangle form according to the composition. In the circle dots represent the number of plants germinated, and a dash the amount of dry matter produced. The diagram therefore shows at a glance the composition of the salt mixtures, the germination obtained, and the dry weight of the crop for any one concentration. Each concentration of salts is represented by another diagram and the series gives a very intelligent and comprehensive view of the results he obtained in his experiment. In the particular illustration here shown it becomes readily apparent that with increasing concentration, germination is interfered with, and that this shows itself first in the $(NH_4)_2CO_3$ section, and later also in the K_2CO_3 section, with the least effect in the Na_2CO_3 section. Similar results are apparent in the growth line in the series of diagrams. This is a striking illustration of the varied usefulness of having a definite fundamental plan in the experiments which permits handling complicated results in a

simple manner, both for the purpose of experimentation, recording the results, and presenting them in a clear, concise, and logical way to others.

This triangular system has been used and amplified by Tottingham,[7] while working at the Johns Hopkins University, in his rather com-

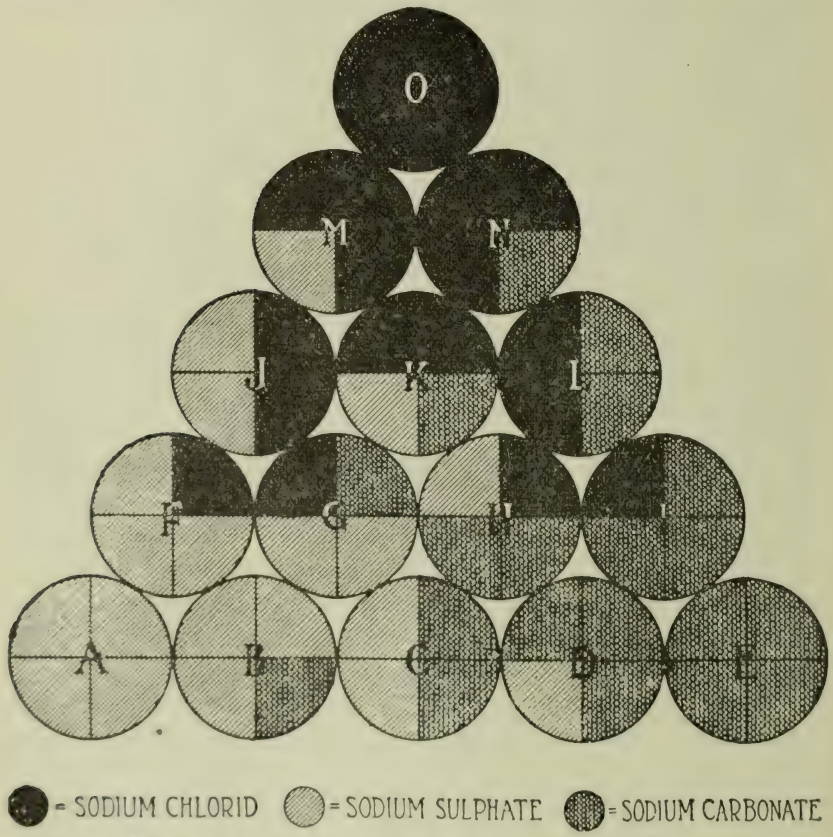

FIG. 36. Diagram showing percentage of salts, mixtures, and their position in the diagrams of experimental sets, as used by Harris. Variations in 25-percent stages.

prehensive physiological study of nutrient solutions, for the details of which the reader is referred to the original article. Likewise Shive,[8] in following up this subject at the same institution, used the

[7] Tottingham, W. E. A quantitative chemical and physiological study of nutrient solution for plant cultures. *In* Physiological Researches, vol. 1, no. 4, p. 133-245. 1914.

[8] Shive, J. W. A study of physiological balance in nutrient media. *In* Physiological Researches, vol. 1, no. 7, p. 327-397. 1915.

triangular system with good effect. Both of these workers omitted the outside lines of the triangle, confining themselves to the more complete mixtures represented by the interior of our triangle system. Both investigators made up their solutions on the basis of osmotic pressure instead of percentages. The salts used by Tottingham were $Ca(NO_3)_2$, KNO_3, KH_2PO_4, $MgSO_4$, while Shive omitted the KNO_3 as contributing no ions not supplied by the other salts. More recently Wolkoff[9] at Rutgers College, in continuing the work of Shive, substituted $(NH_4)_2SO_4$ for the KNO_3 in Tottingham's solution, using the triangle for study and interpretation. For the results obtained by these workers the originals must be consulted.

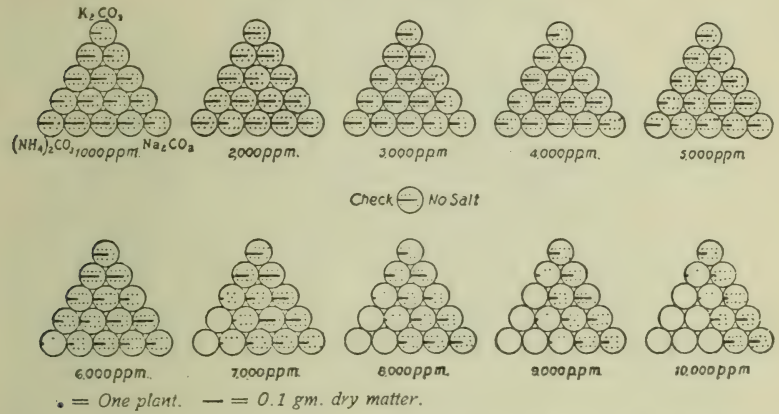

FIG. 37. Method of representing results as used by Harris. Diagram showing the number of wheat plants up and dry matter produced in 24 days on Greenville loam with ammonium carbonate, sodium carbonate, and potassium carbonate in different combinations and concentrations.

McCall[10] has also used our triangle system with interesting results in his work on the physiological balance of nutrient solutions. The salts used were calcium nitrate, magnesium sulfate, and potassium acid phosphate. The composition of his solutions used in sand cultures are represented by the diagram reproduced in figure 38. The variations are in 10-percent stages, but McCall, like Tottingham and Shive, omits the outside lines which comprise the constituents alone and the combinations of two, confining himself to a consideration of the variously constituted mixtures of the three components.

[9] Wolkoff, M. I. Effect of ammonium sulphate in nutrient solution on the growth of soybeans in sand cultures. *In* Soil Science, 5: 123–150. 1918.

[10] McCall, A. G. The physiological balance of nutrient solutions for plants in sand cultures. *In* Soil Science, 2: 207–253. 1916.

True and Bartlett,[11] in their study of the exchange of ions by plants growing in solution cultures, used this system. The salts used were the nitrates of potassium, calcium, and magnesium. The composition is stated in terms of concentration as to normality instead of on a percentage basis. The plan is reproduced in figure 39. Each point

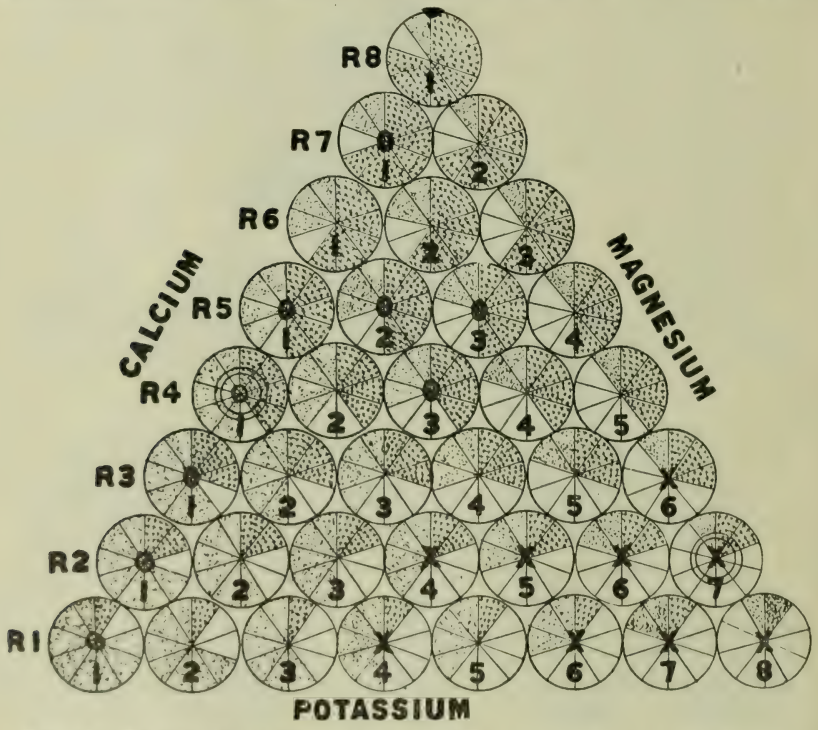

FIG. 38. Triangular diagram used by McCall, showing the arrangement of the sand cultures with respect to the partial concentrations of the three salts employed. Unshaded segments represent the proportions of $Ca(NO_3)_2$: stippled segments the $MgSO_4$: and the segments shaded with crosses the KH_2PO_4. The best nine cultures are marked X, while the poorest are marked O.

in the figure represents a solution, the original composition of which is indicated on the three intersecting lines reading upward from the intersection. The sum of the numerals at the intersection at any point is 140, indicating a total concentration of $140N \times 10^{-6}$. The figures given at the intersections for the residual concentration at the time

[11] True, R. H., and Bartlett, H. H. The exchange of ions between the roots of *Lupinus albus* and culture solutions containing three nutrient salts. *In* Amer. Jour. Botany, 3: 47–57. 1916.

of maximum absorption are based on the original concentration, in each case, $140N \times 10^{-6}$ being considered as 1.000.

True[12] also used the triangle system in his study of the effects of calcium in its relation to plant nutrition.

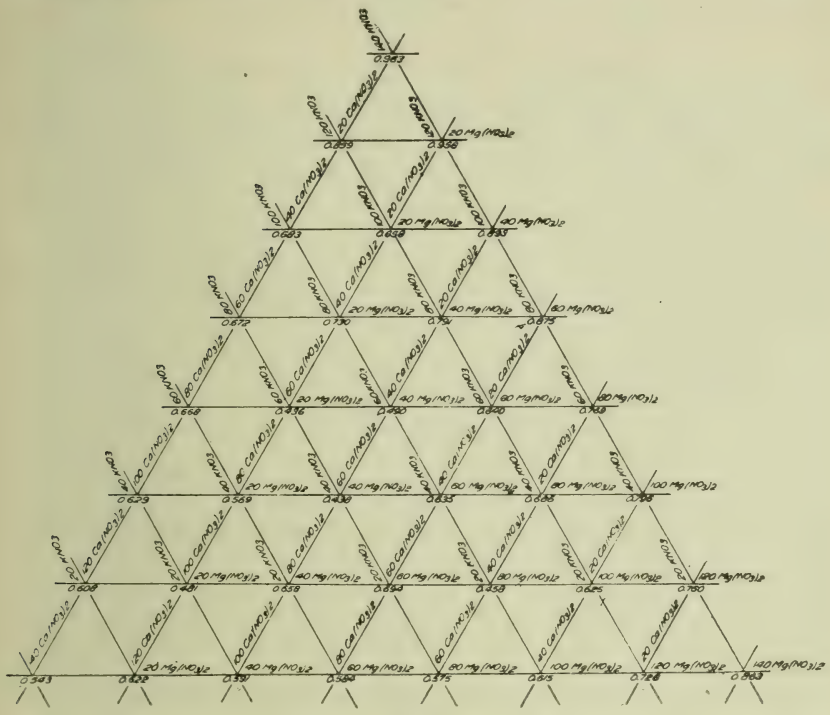

FIG. 39. Triangular diagram as used by True and Bartlett, in showing the residual concentration of solutions containing KNO_3, $Ca(NO_3)_2$, and $Mg(NO_3)_2$, at the time of maximum absorption.

Chamot[13] used the triangular diagram in connection with a study of certain media employed for the bacteriological examination of water. In using the triangular diagram there were considered (1) the concentration of peptone, (2) the concentration of the inorganic salts present, and (3) the nature of the reaction of the medium. He

[12] True, R. H. Calcium in its relation to plant nutrition. Presented before the American Society of Agronomy at its Washington meeting, 1917. Unpublished.

[13] Chamot, E. M., and Redfield, A. W. I. The Schardinger-Dunham medium for testing for the presence of hydrogen sulphide forming bacteria. *In* Jour. Amer. Chem. Soc., **37**: 1606–1630. 1915.

Chamot, E. M., and Sherwood, C. M. II. Lactose-peptone media. *In* Jour. Chem. Soc., **37**: 1949–1959. 1915.

also applied it to mixtures of four components, i. e., in addition to those noted above he used carbohydrates, but in this case he followed the procedure already mentioned in connection with the use of toxic organic substances earlier in this paper, viz., by keeping this fourth component constant in all the cultures of the triangle.

The Triangular System in Field Experiments.

Following the use of the triangle system in our solution culture work, the same system was used in field studies on the action of fertilizers. The system was first laid out on the Arlington Farm in 1909, and at the Pennsylvania Agricultural Experiment Station Farm

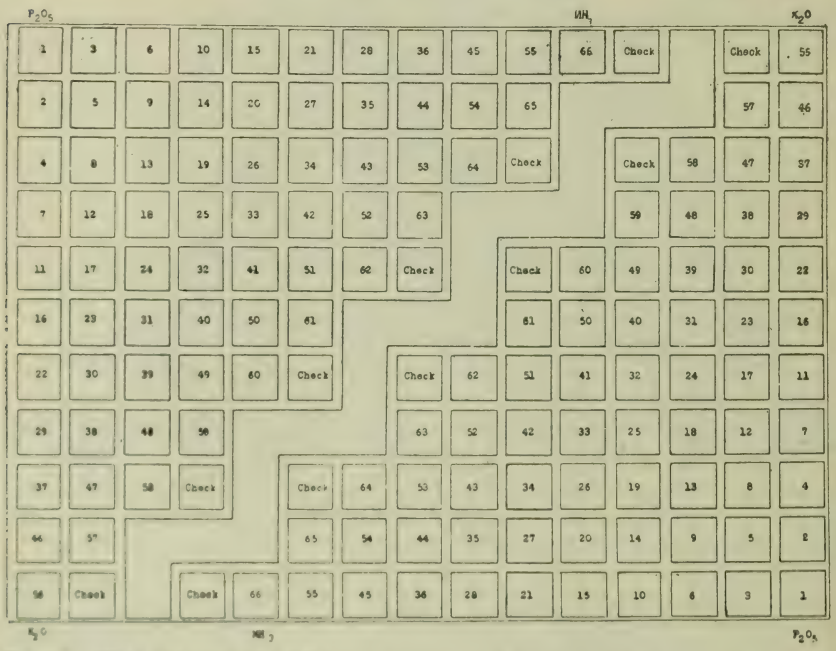

FIG. 40. Plat showing the field arrangement of two triangle systems in small rectangular plats.

in 1910. The plats used are small and therefore arranged in the form of the triangle, although this is by no means a requisite of the system. The checks run across the field diagonally at intervals and a strip of original untreated soil is maintained in sod between the triangles.

At the Pennsylvania Agricultural Experiment Station Farm the fertilizer test is made on grass land. When the experiment was

begun in 1910, the area on which the plats were located had a fairly uniform stand of grass consisting almost entirely of Canada bluegrass, Kentucky bluegrass, and timothy, with a very little white and red clover. It was estimated that Canada bluegrass covered about 50 percent of the area, Kentucky bluegrass about 30 percent, and timothy about 20 percent.

The soil is of the Hagerstown series. The surface soil varies in depth from 7 to 11 inches, and mechanical analyses of the soil and subsoil of plats taken at regular intervals show that the surface soil is silt loam and silty clay loam and the subsoil, clay and silty clay loam.

The plats were laid off according to the triangular system as shown in figure 40. They are 10 feet square and are separated by 2-foot paths. The plats were laid off in duplicate with a 10-foot space separating the two series, or triangles. Besides the 66 treated plats, there are 6 check plats in each series. The unused dividing strip and the 2-foot paths are kept in grass which is cut when the grass on the plats is cut. Here one may study the untreated soil.

As laid out, the two series form a rectangle, and all outside corners of the plats on the boundaries are marked with posts 4×4 inches which extend out of the ground 12 inches. These are outside of the plat so that the inside corner of the post coincides with the outside corner of the plat. For any desired purpose the boundaries of the plats are defined by stretching twine both ways across the two triangles.

The fertilizers have been applied in early April of each year just after the grass began to grow. The fertilizers are weighed out into wide-mouth bottles as previously described. After marking off the plats, the content of each bottle is mixed with about a quart of dry sand and then distributed by hand as evenly as possible. The fertilizer which each plat receives is at the rate of 50 pounds per acre of the active fertilizer constituents.

Some of the results obtained in this grass experiment have been presented in an earlier report,[14] but there are further interesting changes in the composition of the grasses which will form the subject of a later report. These changes in grass composition appear to result from the different fertilizer ratios and we wish here to call particular attention to the use of the triangle system and diagram in

[14] Noll, C. F., Schreiner, Oswald, and Skinner, J. J. Fertilizer ratio experiments with grass on Hagerstown loam. *In* Ann. Rept. Pa. State Coll. for the year 1913–1914, pt. 2, p. 22–36. 1915.

bringing out these facts. Each plat was analyzed botanically and the proportion of Kentucky bluegrass, Canada bluegrass, timothy, red clover, and white clover present stated on a percentage basis. This means 330 figures for each triangle and these are very easily handled by representing each plat or point in the triangle by a circle and letting each grass percentage represent a segment of the circle, much like the diagram of Plate 5, using 3 different shades of green for the three grasses and two shades of red for the clovers. When this is done it becomes strikingly apparent that the clovers are decidedly more prominent in that area of the triangle which is low in nitrogen. Originally Canada bluegrass was predominant. In the higher nitrogen area, Kentucky bluegrass is now predominant and the Canada bluegrass appears to be gradually crowded out. These facts could not have been easily seen or portrayed without the use of the triangular system of experimentation and the use of the diagram in the interpretation of the results.

At the Arlington Farm the manner of laying out the plats and the size are the same as the grass plats just described, but there are four triangles in the experiment. One of these is devoted to the growing of wheat, year after year, while the other three are devoted to a rotation of wheat, corn, and cowpeas, each crop being grown on one of the triangles. Plate 6 shows two general views of the field devoted to this work. Plate 6, figure 1, shows the preparation of the ground for planting after the fertilizers have been applied, the stakes marking the individual plats, while figure 2 shows the harvested crop from the plats.

A similar plan of experimentation was devised for orchard or grove fertilizer tests. Blocks of four or nine trees are selected as a unit for each treatment and careful notes made of their condition. In the case of an orange grove 1 pound of the fertilizer constituents was applied per tree.

In 1917 the Maine Agricultural Experiment Station at Aroostook Farm, near Presque Isle, Maine, inaugurated a fertilizer experiment, using our triangle system and employing 20 percent differences in the fertilizer combinations, as shown in figure 29. The fertilizer carriers in the regular 21 combinations were the phosphate as acid phosphate, the potash as potassium sulfate, and the nitrogen as one-third sodium nitrate and two-thirds ammonium sulfate. In addition a certain mixture was chosen and changes made to include other carriers, as follows: (*a*) For the acid phosphate an equivalent amount of floats is substituted, and (*b*) for the inorganic nitrogen an equivalent amount

FIG. 1. General view of the triangle fertilizer experiments on the Arlington Farm, Virginia. Preparation of the soil.

FIG. 2. General view of the triangle fertilizer experiments on the Arlington Farm, Virginia. Harvesting the wheat.

FIG. 1. General view of triangle fertilizer experiments on potatoes at Presque Isle, Maine. The treatments were arranged in double rows.

FIG. 2. View of triangle fertilizer experiments on potatoes at Presque Isle, Maine. Note the plants dying in the two rows on the left, one of the treatments without potash. Note also the series of darker rows in pairs occurring at intervals. These are the other no-potash treatments.

of organic nitrogen is substituted, both as dried blood and as high-grade tankage. The crops grown are potatoes, oats, and clover in rotation, each crop being grown each year on one of the series of plats. The plats are one-fortieth acre in area. The total quantity of active fertilizer constituents, P_2O_5, NH_3, and K_2O applied per acre is 240 pounds to potatoes, 80 pounds to oats, and 40 pounds to clover The general scheme of the field arrangement of the plats is shown in figure 41.

A further study in which the triangle system was used was in connection with the potash hunger of the potato. In this experiment the 21 treatments were in two rows each of such length as to make one-

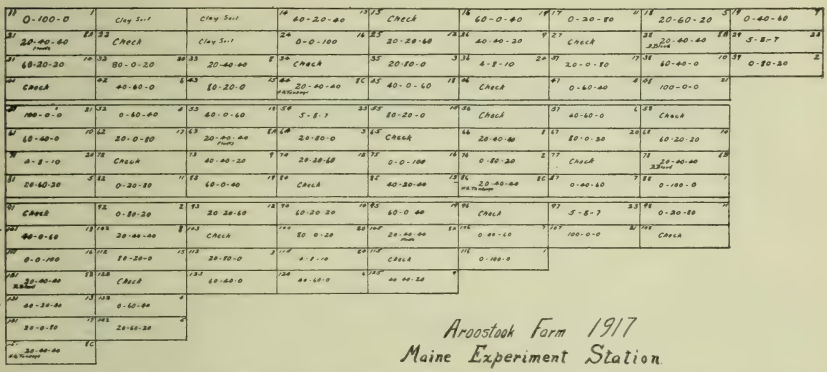

FIG. 41. Plat of the triangle fertilizer experiment at Aroostook Farm of the Maine Agricultural Experiment Station. Plats not arranged in triangle form.

twentieth of an acre for each treatment. Every three treatments or six rows were separated by the insertion of two check rows. The experiment was laid out in a field of which a carefully surveyed and detailed soil map had been prepared. Two soil types with gradations of each were involved and the crop was in each case on both soil types. Each soil type was harvested separately for each treatment. The details of this work and the highly interesting and different results obtained for the two soil types will be reported upon later.[15]

Plate 7, figure 1, shows this field triangle experiment at blooming time. The characteristic symptoms of potash hunger are a deeper green foliage of the plants than is normal, with a crinkled appearance of the leaf, which curves downward. This darker green gives way later to a distinct bronzing of the leaves, which finally die and the

[15] This was a cooperative study of potash hunger of the potato with special reference to soil type differences, carried on by the Bureau of Plant Industry and the Maine Agricultural Experiment Station.

plant collapses completely. Plate 7, figure 2, shows some of the collapsed plants on one of the no-potash plats of the triangle (No. 6) in the foreground. Attention is called to the series of darker lines of two-row treatments which can be distinctly seen even in the photograph and in the field these were very striking indeed. These are the no-potash plats of the triangle with the darker green or bronze-colored foliage characteristic of this trouble. This triangle experiment brought out strikingly the effect which potash in the fertilizers has in controlling this war-time disease, and shows how it is practical to use such a system in farm experimentation for solving fertilizer needs for any particular soil or crop.

RELATIVE EFFECT OF SODIUM CHLORIDE ON THE DEVELOPMENT OF CERTAIN LEGUMES.[1]

G. W. Hendry.

Introduction.

The experiment here reported was initiated to observe the relative reaction to NaCl of certain leguminous crops cultivated extensively in California. Because of the complexity of the problem no effort has been made to arrive at the absolute tolerance of any variety and even the relative tolerance, indicated under the conditions of this experiment, may not be maintained under changed conditions or with other salts or combinations of salts.

Thirteen selected varieties were grown in the greenhouse in 1-quart glass jars filled with chemically pure quartz sand, to which alkali in the form of NaCl was added in five different concentrations, viz., 2,000, 8,000, 15,000, 25,000, and 50,000 parts per million of solution, equivalent to 0.04 percent, 0.16 percent, 0.3 percent, 0.5 percent, and 1.0 percent respectively of alkali based on the dry weight of the sand. In addition each jar was supplied from time to time with plant food in the form of a standard nutrient solution. Each variety was also grown in a culture receiving no NaCl. Sprouted seeds of all varieties were placed in the sand on September 10, but the seeds were placed in the germinator in preparation for the experiment as follows: Windsor bean and garbanzo, September 3; Cranberry, Red Kidney, Bayo,

[1] Contribution from the Division of Agronomy, College of Agriculture, University of California, Berkeley, Cal. Received for publication April 14, 1918.

and lima beans, September 4; Pink, Red Mexican, Lady Washington, Small White, and Blue Pod beans, September 5; and Blackeye cowpea and Tepary bean, September 6. By this progressive arrangement the radicles of all varieties were about 1 inch in length when planted September 10.

Relative Effects of NaCl Concentration on Plant Development.

In Table 1, the varieties are grouped in the order of their apparent resistance to NaCl, and observations are recorded on the comparative effect of alkali concentration on the duration of life, height growth, and total leaf area.

Table 1.—*Relative effects of NaCl concentration on life period, height growth, and leaf area of certain leguminous crops.*[a]

Class and variety.	No. of days plants lived.				Height in inches when 32 days old.				Relative leaf surface,[b] percent.			
	Check.	NaCl 0.04 per-cent.	NaCl 0.16 per-cent.	NaCl 0.3 per-cent.	Check.	NaCl 0.04 per-cent.	NaCl 0.16 per-cent.	NaCl 0.3 per-cent.	Check.	NaCl 0.04 per-cent.	NaCl 0.16 per-cent.	NaCl 0.3 per-cent.
Most tolerant:												
Blackeye cowpea	[c]90	[c]90	[c]90	[c]90	14.0	14.0	6.5	4.5	100	94.0	16.7	8.0
Windsor bean	[c]90	[c]90	[c]90	67	32.0	22.0	19.0	9.0	100	60.0	30.7	9.3
Mexican garbanzo	[c]90	[c]90	66	59	23.0	25.0	16.0	11.0	100	76.4	50.0	15.0
Moderately tolerant:												
Lewis lima	[c]90	[c]90	[c]90	50	54.0	27.0	10.0	6.5	100	51.0	20.0	3.1
White tepary	[d]90	[d]90	[d]90	44	52.0	42.0	32.0	6.7	100	75.2	27.5	6.0
Least tolerant:												
Cranberry	[d]85	[d]85	....	40	42.0	32.0	....	6.0	100	51.9	....	
Small white	[d]90	[d]90	[d]90	31	52.0	32.0	7.0		100	98.0	29.5	
Red kidney	[d]90	[d]90	71	31	19.0	20.0	10.5		100	40.5	12.7	
Lady Washington	[d]86	[d]86	56	31	27.0	11.0	6.5		100	61.1	14.7	
Pink	[d]76	[d]81	50	31	11.0	9.5	7.0		100	40.0	8.4	
Red Mexican	[d]86	[d]86	50	31	10.0	9.5	5.0		100	71.0	4.7	
Bayo	[d]90	....	61	15	29.0	....	2.3		100	....	47.1	
Blue pod	[d]90	[d]90	46	10	48.0	36.0	6.0		100	90.5	17.8	

[a] None of the plants grew in the 1.0 percent solution of NaCl. In the 0.5 percent solution only the Windsor bean and the Mexican garbanzo survived, both of them living for 45 days. The former reached a height of 1 inch and the latter of 4 inches, while the relative leaf surfaces were reduced to 3.6 and 2.0 percent of their respective checks.

[b] The relative leaf surface is expressed in terms of leaf coefficient or average number × average length × average width. Taken when plants were 46 days old.

[c] Still growing when experiment was stopped.

[d] Ripened seed.

The groupings employed in Table 1 are based principally upon the data contained therein, but were influenced somewhat, particularly in the arrangement of the varieties within the groups, by the more intangible qualities of general thrift and vigor. It is significant that each of the varieties in the first (most tolerant) group, Blackeye cowpea (*Vigna sinensis*), Windsor bean (*Vicia faba*), and Mexican garbanzo (*Cicer arietinum*), represents a different genus from any of the others; and that the varieties in the second group (moderately tolerant), Lewis lima (*Phaseolus lunatus*) and White tepary (*P. acutifolius* var. *latifolius* Freeman), both represent different species from those in the last group (least tolerant), all of which are varieties of *Phaseolus vulgaris*.

Relative Effects of NaCl Concentration on Nodule Development.

Nodules of nitrogen-fixing bacteria developed naturally on all varieties excepting the lima, tepary, and garbanzo, and were most numerous and largest in each instance in the check culture, diminishing in number and size as the strength of the solution increased, and disappearing entirely in the soils containing NaCl equivalent to 0.3 percent and 0.5 percent on the dry basis. The fact that the nodules on the Windsor bean were apparently less injured by NaCl than those on the Blackeye cowpea suggests that the organisms themselves may possess specific alkali tolerance. Some observations bearing upon this relationship are given in Table 2.

Table 2.—*Relative effects of NaCl concentration on nodule development.*

Variety.	Average number of nodules per plant.				Average diameter of nodules in mm.			
	Check.	NaCl 0.04 per-cent.	NaCl 0.16 per-cent.	NaCl 0.3 per-cent.	Check.	NaCl 0.04 per-cent.	NaCl 0.16 per-cent.	NaCl 0.3 per-cent.
Windsor bean	110	85	50	0	2.0	4.0	2.1	.....
Small white bean	50	35	6	0	3.75	2.0	1.5	.....
Bayo bean	40	.....	15	0	5.5	.....	3.0	.....
Blackeye cowpea	16	0	0	0	3.8	.....	.....	.....

Relative Effects of NaCl Concentration on Blossoming Period.

The occurrence of the blossoming period was retarded by the presence of NaCl in the soil, and the period of retardation increased as the concentration of salt became greater. The retardation was more in some varieties than in others. The Pink bean, however, was an exception, blossoming simultaneously in all cultures, includ-

ing the check, independently of salt concentration. There was no apparent correlation between the period of retardation in blossoming and alkali resistance. Observations on the blossoming periods of six varieties are recorded in Table 3.

TABLE 3.—*Relative effects of NaCl concentration on blossoming periods of several legumes.*

Variety.	Date of opening of the first blossoms.			Total period of retardation in 0.16 percent solution.
	Check.	NaCl 0.04 percent.	NaCl 0.16 percent.	
				Days.
Windsor bean	Oct. 12	Nov. 5	Nov. 8	27
White tepary	Oct. 20	Oct. 22	Oct. 26	6
Red kidney	Oct. 12	Oct. 30	Nov. 3	22
Pink	Oct. 8	Oct. 8	Oct. 8	0
Lady Washington	Oct. 17	Oct. 27	Nov. 10	24
Small white	Oct. 22	Oct. 25	Nov. 8	17

SUMMARY.

The Windsor bean (*Vicia faba*), the Blackeye cowpea (*Vigna sinensis*), and the Mexican garbanzo (*Cicer arietinum*), were less affected by NaCl than the other varieties tested.

The Lewis lima (*Phaseolus lunatus*), and the White tepary (*P. acutifolius* var. *latifolius* Freeman), were less affected by NaCl than any of the varieties of *Phaseolus vulgaris* tested.

The visible effects of NaCl upon the development of the plants was as follows:

1. Retardation of germination;
2. Retardation of height growth;
3. Reduction of the number of leaves;
4. Reduction of the size of the leaves;
5. Retardation of the blossoming period;
6. Reduction in the number of nodules;
7. Reduction in the size of the nodules; and
8. Premature death.

RELATION BETWEEN YIELD AND EAR CHARACTERS IN CORN.[1]

T. B. Hutcheson and T. K. Wolfe.[2]

In recent years some doubt has arisen as to the value of certain score-card points as a criterion for selecting high-yielding strains of corn. The question is, do the points emphasized on the score card have any relation to the yielding capacity of the individuals possessing these characters? It would be of great importance to determine which of these points are and which are not indicative of high yield, if any relation at all exists. Considerable work has been done along this line, some of which will be reviewed briefly in this paper.

The usual method in studying the relation of ear characters to yield has been to select ears with the characters desired and then obtain the yield from these selected ears when planted. In this method of procedure, there is likely to be some variation in the yield of different ears, due to cross-pollination. It is well known that the effect of broad breeding in corn is often marked. It may be that this effect has overshadowed differences in yield due to different characters possessed by the selected ears.

The data in this paper deal with the relation between yield and ear characters of the progeny of certain seed ears selected at random. The characters studied in relation to yield are average length, average circumference, ratio of tip to butt circumference, average circumference of cob, percentage of grain, average number of rows, average length of kernels, uniformity of exhibit, shape of ears and trueness to type, character of tips, character of butts, uniformity of kernels, space between kernels, and space between rows.

Review of Literature.

In extensive experiments conducted at the Ohio (10)[3] station it was found that there was no material relationship between various seed ear characters and yield.

[1] Paper No. 4, Department of Agronomy, Virginia Agricultural Experiment Station, Blacksburg, Va. Received for publication April 28, 1918.

[2] The writers wish to acknowledge the valuable assistance of Mr. S. C. Harman in obtaining the measurements reported in this paper.

[3] Numbers in parentheses refer to "Literature cited," p. 255.

Love (4) obtained a slight increase in yield from planting long ears and from planting heavy ears. However, such seed ear characters as number of rows, average weight of kernel, and ratio of tip to butt did not have any marked effect on yield.

Love and Wentz (5) studied the relation of such seed ear characters as length, average circumference, average cob circumference, weight of ear, number of rows, average weight, average length, average width of kernels, and percentage of grain to yield. The average circumference of the seed ear was the only character which showed any significant relation to yield. The writers conclude that "the only basis left for selecting high-yielding seed corn is the ear-to-row progeny test."

Hartley (2), studying four varieties of corn over a period of six years, in which more than 1,000 ear-to-row tests of production were made, obtained results indicating that no visible characters of apparently good seed ears are indicative of high yielding capacity.

Pearl and Surface (8), in a two years' ear-to-row test, found that there was no evidence of any close association or correlation between the size and conformation of the seed ear and the yield of corn obtained from it on planting.

McCall and Wheeler's (6) experiments indicate that neither length, weight, nor density of ear is correlated with yield.

Sconce (9), in studying the relation between various seed ear characters to yield in the Reid Yellow Dent and Johnson County White varieties, found that ears containing 18 or 20 rows gave the highest yield. In Reid Yellow Dent, small-germ kernels gave the best results, but the large-germ kernels of Johnson County White gave the highest yield. The relation of shape of kernel and yield is striking in both varieties used. The writer states: "The kernel of ideal shape, which tapers slightly and has the square shoulders and full tip, has been giving the best results. Not once since beginning the experiment has an ill-shaped kernel on the average outyielded the ideally shaped kernel."

Montgomery (7) found that the long, smooth type of seed ears outyielded the standard type ears. Also, extra large ears are no more valuable than medium-sized ears for seed purposes.

In an experiment conducted at the Iowa station (3) 500 ears of corn were secured from the field without any selection and scored by twenty-five judges. A portion of each ear was planted in the field; the first year's results indicate that the ears receiving the highest scores were also the most productive in the field. As compared with

the bulk of the ears, the fifty best ears, as selected by the majority of the judges, yielded on the average 5 bushels more to the acre.

Experiments conducted by Cunningham (1) indicate that the length of ear has little relation to yield, but that varieties differ in this respect. The indications are that slender seed ears are more productive than those of comparatively large circumference. There was apparently no relation between the character of tips and butts and percentage of grain to cob to yield. It was found that ears of intermediate indentation outyielded smooth or rough ears, while the rough consistently yielded lower than the smooth ears. The relation of number of rows to yield varied with different varieties.

Material and Methods.

The corn used in this work was Boone County White, which has been grown at the experiment station for nine years and selected for earliness. By selection a strain has been developed adapted to the mountain sections of the State. This strain matures about ten days to two weeks earlier than other strains of this variety which have not been selected for earlines.

All measurements were taken in inches and the yield expressed in bushels per acre. In 1916, 140 ears were planted in the ear-to-row test; in 1917, 98 ears were planted. These ears were selected at random and two rows 66 feet long were planted from each ear, the two rows constituting one one-hundredth of an acre. At husking time the grain from the two rows produced by each ear was combined and later shelled and the yield per acre computed. Each year, before shelling, a certain number of high-yielding and low-yielding strains were selected and the data secured which are presented in this paper. The average circumferences of the ear and of the cob were obtained by averaging the butt and tip circumferences. The ratio of tip circumference to butt circumference was obtained by dividing the former by the latter. In this way the shape of the ear was determined. The nearer this ratio approaches unity the more cylindrical is the ear. The percentage of grain was calculated by dividing the weight of shelled corn by the weight of grain and cob. The number of rows was determined by counting the rows on ten ears of each strain selected. The average length of kernels was found by subtracting the average circumference of the cob from the average circumference of the ear. The length of the kernels was then calculated by the formula, circumference $= 2\pi r$ (r = radius or length of kernel). Each strain selected was scored by use of the corn score card adopted by the

station and corn growers of this State. Data were secured by use of the score card on the following characters: Uniformity of exhibit, shape of ears and trueness to type, character of tips, character of butts, uniformity of kernels, shape of kernels and size of germs, space between rows, and space between kernels. The value of these latter characters is expressed in percentages, 100 percent being a perfect score.

Results.

In Table 1 data are presented showing the relation between yield and various ear characters of the progeny of a number of ears of Boone County White corn planted in the ear-to-row test.

Table 1.—*Relation between yield and various ear characters of the progeny of different ears of Boone County White corn at the Virginia station in 1916 and 1917.*

Character.	High yielding strains.		Low yielding strains.		Average.	
	1916.	1917.	1916.	1917.	High yielders.	Low yielders.
Average length, in.	8.61	8.31	8.30	7.65	8.46	7.98
Average circumference, in.	6.90	6.70	6.69	6.46	6.80	6.57
Ratio of tip to butt circumference	.85	.88	.84	.87	.86	.86
Average circumference of cob, in.	4.09	4.29	3.97	4.08	4.19	4.03
Yield, bushels per acre	82.74	62.30	61.97	47.58	72.52	54.78
Percentage of grain	85.27	79.46	83.97	80.57	82.37	82.27
Average number of rows	16.77	16.51	16.57	16.35	16.64	16.46
Average length of kernels, in.	.45	.38	.43	.38	.42	.41
Uniformity of exhibit, percent	55.00	49.44	48.00	48.18	52.22	48.09
Shape of ear and trueness of type, percent	55.42	41.67	50.50	38.64	48.55	44.57
Character of tips, percent	60.83	26.11	47.00	25.50	43.47	36.25
Character of butts, percent	59.17	39.44	55.00	40.91	49.31	47.96
Uniformity of kernels, percent	55.83	43.89	56.00	35.45	49.86	45.73
Shape of kernels and size of germ, percent	64.58	40.56	53.50	40.45	52.57	46.98
Space between kernels, percent	71.25	53.33	71.50	52.27	62.29	61.89
Space between rows, percent.	69.58	45.56	65.00	52.73	57.57	58.87

In 1916 twelve high-yielding and ten low-yielding strains were selected. The high-yielding strains contained 756 ears which were measured for length and 716 ears measured for circumference. The low-yielding strain contained 439 ears which were measured for length and 418 measured for circumference.

In 1917 nine high-yielding and eleven low-yielding strains were

selected. In the high-yielding strains 514 ears were measured for length and 500 ears for circumference. In the low-yielding strains 540 ears were measured for length and 534 for circumference.

A study of Table 1 shows that in 1916 the high-yielding strains produced 20.77 bushels more per acre than the low-yielding strains. Also, the data obtained in that year are in favor of the high-yielding strains in every case save two, uniformity of kernels and space between kernels. In these two instances, the differences are slight, 0.17 percent, and 0.25 percent respectively. In 1917, the difference in yield is 14.72 bushels. In this year the results are in favor of the high yielding strains in all instances save three, namely, percentage of grain, character of butts, and space between rows. The differences in these three instances are 1.11 percent, 1.47 percent and 7.17 percent, respectively. If the averages for the two years are considered, we find that the results are in favor of the high-yielding strains in every instance, except in the case of the space between rows. The difference here is 1.30 percent in favor of the low-yielding strains.

The negative relation between yield and space between rows is not surprising when the origin of the strain of corn is considered. As stated before, the strain has been developed especially for early maturity and in so doing a type has been secured with a rather greater distance between the rows than in the original variety.

The results for the two years are in close accord and are very suggestive. The data indicate that the points emphasized in the corn score card may be of value in selecting high-yielding strains. In other words, according to our results, high-yielding strains are high-scoring strains.

These results are more interesting when the prize-winning varieties of corn in Virginia are considered. For many years the standard varieties of corn in the State, based on yield and other desirable characteristics, have been Boone County White, Johnson County White, Collier Excelsior, Reid Yellow Dent, and Gold Standard. These varieties are not only the high-yielding varieties of the State, but are the ones which have taken the greater part of the prizes annually at the State fairs and at the fairs held by the State Corn Growers' Association, where the score card is used as a basis for awards.

Conclusions.

The data reported in this paper indicate that:

1. The relation between yield and length, average circumference,

average circumference of cob, uniformity of exhibit, shape of ears and trueness to type, character of tips, uniformity of kernels, and shape of kernels and size of germ is significant.

2. The relation between yield and ratio of butt to tip circumference, percentage of grain, number of rows, average length of kernels, character of butts, space between kernels, and space between rows is small.

3. The points emphasized on the score card are of value in selecting high-yielding strains of corn.

4. High-yielding strains of corn are high-scoring strains.

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INFLUENCE OF CEROTOMA TRIFURCATA ON THE NITROGEN-GATHERING FUNCTIONS OF THE COWPEA.[1]

LEWIS T. LEONARD and C. F. TURNER.

INTRODUCTION.

The nodules of leguminous plants are recognized as fundamental sources of nitrogen for plant growth and any agency which tends to impede their normal formation or interfere with their nitrogen-fixing functions is worthy of scientific consideration. For a long time it has been known that the physical, chemical, and bacteriological forces of the soil influence the production of nodules, but recently McConnell[2] called attention to the destruction of the nodules of various legumes by the larvæ of the bean-leaf beetle, *Cerotoma trifurcata* Forst. McConnell has also reported[3] the destruction of nodules of wild legumes by the larvæ of *Eudiagogus rosenschoeldi* Fahrs in Mississippi and Arkansas. The first-mentioned beetle in its adult form is very destructive to the leaves of the legumes which it will attack, but this injury is quite noticeable, whereas the injury done by the larvæ to the roots and tubercles represents a type which is not evidenced by any superficial symptoms which the ordinary observer might consider (Plate 8, fig. 1). The cowpea and the garden bean are reported to be the principal plants which are subject to the ravages of these insects. As the cowpea is one of the most important legume crops in the sections where the beetles are apparently most destructive it was chosen for use in these experiments to determine the factors governing this type of injury.

It was at first thought that results could be obtained by conducting experiments in the vicinity of Washington D. C., and in 1914 field and can experiments were carried on at the Arlington Farm, Rosslyn, Va., but the results were vitiated by a cold, rainy season. Similar experiments of a more comprehensive character were conducted in

[1] Contribution from the Bureaus of Plant Industry and Entomology, U. S. Department of Agriculture, Washington, D. C. Received for publication April 5, 1918.

[2] McConnell, W. R. A unique type of insect injury. *In* Jour. Econ. Ent., 8: 261–267. 1915.

[3] McConnell, W. R. Another nodule destroying beetle. *In* Jour. Econ. Ent., 8: 551. 1915.

1915 at the same place, but the results did not justify their continuation. It was evident that climatic conditions obtaining in the latitude of Washington were not conducive to the normal life of the insect, regardless of the fact that Cerotoma beetles have been collected in this vicinity and as far north as New Jersey. The beetles used in these initial trials were collected in Mississippi and the eggs were oviposited at the Bureau of Entomology Field Station, Hagerstown, Md. It is possible that the strains of larvæ and beetles developing under abnormal conditions lacked the virility to function properly in the northern climate.

As the results at Washington were inconclusive and entirely unsatisfactory, it was decided to continue the experiments in the vicinity of Greenwood, Miss., under the direct supervision of the Federal entomological substation there.

Experimental Data.

These experiments were carried out during the summer of 1916. Similar plots were arranged at Greenwood, Miss., on the rich black delta soil and at Grenada, Miss., on the poorer reddish hill soil. The location of these plots was determined on the basis of soil uniformity, contour of land, and proximity to fields planted or to be planted in cowpeas. These plots were cleared of all debris considerably before planting time so as to make the hibernating insects seek other quarters or die from exposure. Each plot was plowed and subdivided into smaller plots 4 feet square centered in 12-foot squares, thereby leaving a clear space 4 feet in width around each small plot. Before breaking ground the Greenwood plot was in grass and weeds while the one at Grenada was in clover.

Cages to protect the small plots from outside infestation and to restrict the travel of beetles introduced or developed in the cages were made from ¾-inch lumber and 18-mesh wire screen. The outside dimensions of the cages were 4 feet by 4 feet by 2½ feet. They were strongly built and well braced.

These cages were arranged in the order shown below.

Final Arrangement of Experimental Plots at Greenwood, Miss.

1	2	3	4	5	6	7
A	B	C	O	A	B	C
14	13	12	11	10	9	8
A	C	A	O	A	C	A
15	16	17	18	19	20	21
C	A	B	O	C	A	B

FINAL ARRANGEMENT OF EXPERIMENT PLOTS AT GRENADA, MISS.

1	2	3	4	5	6	7
A	C	B	O	A	B	C
14	13	12	11	10	9	8
A	C	A	O	A	C	A
15	16	17	18	19	20	21
C	A	B	O	C	A	B

The smaller plots were numbered for convenience in handling samples.

Plots marked A were entirely inclosed in cages and twenty pairs of Cerotoma beetles were introduced into each except those in the center row bearing the numbers 8, 10, 12, and 14, into each of which forty Cerotoma eggs were inserted.

Plots marked B were covered with cages which were slightly elevated above the ground on one side to allow for normal infestation in conjunction with plants shaded by cages (Plate 8, fig. 2).

Plots marked C were inclosed the same as those marked A, but were not infested with beetles or eggs. These plots were devised to act as checks on the inclosed infested plots.

Plots marked O were not covered and served the purpose of open controls.

The cages from which it was intended to prevent outside infestation by beetles or larvæ were sunk 6 inches in the ground up to the top of the baseboard and precautions were taken to make them secure by filling all cracks and holes.

New Era cowpeas were planted in the small plots at Greenwood May 6, 1916, and at Grenada, May 25, 1916. Infestation was accomplished in accordance with the plans at Greenwood, June 14, 1916, and at Grenada, June 16, 1916. At the time of infestation the number of plants per plot was reduced to six. The crop was harvested at Greenwood, July 22, 1916, and at Grenada, August 2, 1916. The cowpea vines were cut about 3 inches from the ground. This forage was stored in cotton bags and dried in the sun. At the same time the crop was cut the roots were dug carefully and data taken on the total number of nodules per plot and the percentage of nodules injured by Cerotoma larvæ. The roots were also dried.

In the second series of experiments the plots at Greenwood were planted with Whippoorwill cowpeas August 7, 1916, and those at Grenada, August 9, 1916. Infestation in exactly the same quantities and manner as in the earlier experiments was introduced at Green-

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FIG. 1. Cerotoma larvæ feeding on cowpea nodules and the character of the injury made. (Magnified 5 times.)

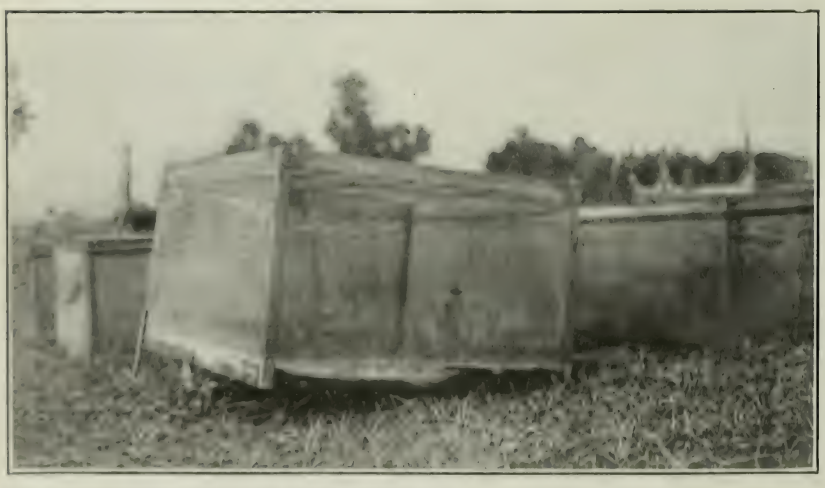

FIG. 2. Type of cage used and method of tilting to secure natural infestation.

wood, September 2, 1916, and at Grenada, September 5, 1916. As in the other experiments the number of plants were reduced to six.

These experiments were concluded at Greenwood October 17, 1916, and at Grenada October 18, 1916. Except for the collection of composite soil samples for nitrogen and bacteriological analyses the crop was treated the same as before and similar data obtained.

The material was dried in Mississippi and shipped to Washington, where it was carefully weighed and ground to a powder. The Bureau of Chemistry kindly made the nitrogen analyses recorded in Table 1.

TABLE 1.—*Summary of results obtained in experiments to determine Ceretoma injury to cowpeas in 1916.*

NEW ERA COWPEAS AT GREENWOOD, MISS.

Plot.[1]	Soil nitrogen, percent.	Soil-nitrifying bacteria per gram.	Ave. number of nodules per plot.	Percent of nodule injury.	Ave. total dry weight.	Percent of nitrogen.		Total nitrogen, grams.
						Tops.	Roots.	
A (Introduced beetles).	0.17	11,687,500	207.50	95.35	278.38	2.40	1.28	6.32
B (Normal infestation).	0.18	14,250,000	263.50	67.08	240.38	2.80	1.55	6.56
C (Covered check).....	0.24	7,000,000	373.33	42.37	238.83	2.67	1.72	6.24
A (Introduced eggs)...	0.38	5,750,000	284.50	59.63	197.38	2.75	1.72	5.26
O (Open check).....	0.16	12,500,000	442.67	93.40	457.17	2.60	1.51	11.64

NEW ERA COWPEAS AT GRENADA, MISS.

A (Introduced beetles).	0.04	245,000	217.00	76.18	73.88	2.11	1.08	1.42
B (Normal infestation).	0.03	375,000	183.25	61.10	110.25	2.42	1.31	2.50
C (Covered check).....	0.06	215,000	173.67	60.59	97.17	2.10	1.16	1.90
A (Introduced eggs)...	0.03	232,500	177.50	65.53	93.13	2.47	1.26	2.16
O (Open check).....	0.04	370,000	198.00	79.03	85.80	2.13	1.27	1.73

WHIPPOORWILL COWPEAS AT GREENWOOD, MISS.

A (Introduced beetles).	0.17	11,687,500	102.50	49.08	96.38	2.77	1.35	2.49
B (Normal infestation).	0.18	14,250,000	95.50	44.88	26.63	3.07	1.37	.74
C (Covered check).....	0.24	7,000,000	195.17	10.77	121.42	2.73	1.60	3.16
A (Introduced eggs)...	0.38	5,750,000	122.75	21.12	114.50	2.91	1.51	3.14
O (Open check).....	0.16	12,500,000	6.67	80.50	1.67		0.51	0.01

WHIPPOORWILL COWPEAS AT GRENADA, MISS.

A (Introduced beetles).	0.04	245,000	137.75	46.10	22.00	2.71	1.14	0.52
B (Normal infestation).	0.03	375,000	110.75	20.25	11.38	3.11	1.46	0.30
C (Covered check).....	0.06	215,000	150.67	10.02	21.63	2.78	1.23	0.54
A (Introduced eggs)...	0.03	232,000	94.50	42.88	14.50	2.65	1.17	0.35
O (Open check).....	0.04	370,000	29.67	73.00	3.67	0.69	0.46	0.02

[1] In the above summary data following A, B, C, A eggs, and O represent the average of 4, 4, 6, 4 and 3 plots respectively.

Discussion of Results.

As will be noted in the summary of results, the second experiment, in which Whippoorwill cowpeas were used, is more striking than the first experiment, in which New Era cowpeas were used. This is probably due to factors such as planting time, climatic conditions, etc., rather than to the variety of cowpea.

The average of the dry weights of the New Era cowpeas from the open check plots at Greenwood is greater than the average weight of any of the other series of plots. It is evident that the plants in this particular set of open checks were well started and growing vigorously before the larvæ made an extensive attack on the roots. This factor coupled with climatic conditions and the natural richness of the soil will probably explain this apparently abnormal production of forage while the inclosed plots were somewhat hindered in their development by the unnatural conditions imposed upon them.

It is to be regretted that the inclosed check plots became infested in spite of the precautions taken. The presence of infestation in these cages may be explained on the ground that small female beetles crawled through the meshes of the screen or through the cracks at the corners of the cages made by the drying influence of the hot weather.

The results indicate that the nodule injury is related to the percentage of nitrogen in the roots. As the injury of the nodules increases the percentage of nitrogen in the roots decreases, or nitrogen lost is in proportion to the number of larvæ present. It should be noted that there was considerable damage done to the leaves of the cowpeas, much more in the second series of experiments than the first. The maximum damage to leaves apparently occurred in the B plots, although leaves were injured in practically every plot. The open check plots in the second series produced very spindly plants and the injury observed here was probably due almost entirely to the attacks of the larvæ on the roots.

The destructive character of the damage which may be done by these larvæ is shown rather forcibly in the experiments with Whippoorwill cowpeas; the plants did not develop much beyond the cotyledon stage.

Cowpea bacteria will fix atmospheric nitrogen in the nodules to the extent of approximately two thirds of the nitrogen obtained by the plant. Considering the Whippoorwill cowpea experiment at Greenwood we find that the bacteria took from the air an average of about 2.10 grams of nitrogen in the inclosed checks or C plots, and

in the open check plots an average of about 0.006 grams. A comparison of these two estimates will indicate an approximation of the damage it is possible for these insects and their larvæ to perpetrate. There is no doubt that the larvæ and beetles are high in nitrogen and to some extent excrete the nitrogen they consume in the soil surrounding the cowpeas on which they feed. Analyses of beetles indicated that in the air-dry state they contained 9.65 percent nitrogen, while air-dry larvæ contained 8.73 percent nitrogen. However, as it is possible for these insects during their life cycle practically to kill cowpea plants it will be readily seen that they constitute a direct or indirect menace to the nitrogen-gathering power of the cowpea.

The average total nitrogen fixed by the nodule bacteria in the Whippoorwill Greenwood-B plots or plots exposed at the bottom only is estimated to be about 0.50 gram, showing that the damage was limited to some extent by the covering. In the same series of plots it will be noticed that the A plots which were treated with beetles averaged a gain of amospheric nitrogen of about 1.86 grams, the artificially introduced beetles not doing as much damage as those which entered through normal infestation. The A plots which were treated with eggs took from the air about the same amount of nitrogen per plot as did the inclosed checks.

The dry weight column follows practically the same trend as the total nitrogen column and the percentage of nitrogen contained in the tops is fairly constant when the open checks in the second series are not considered.

Conclusions.

1. Danger of extensive damage from Cerotoma beetles or their larvæ in the vicinity of Washington is slight.

2. Damage to the mutual nitrogen-fixing functions of the cowpea plant may be caused by these insect larvæ without superficial indication of such damage except the presence of the beetles and leaf injury.

3. Time of planting and preseason conditions are important factors in lessening the extent of damage. Planting should be done after the over-wintered beetles have laid their eggs; for the latitude of Greenwood, Miss., May 1 to 15 is the proper time. Rotation of crops, fall plowing, and clean culture will probably prove beneficial, but further work will demonstrate the efficacy of these methods.

4. Damage may range from practically nothing to the entire destruction of the plant.

5. The damage to the nitrogen content of cowpea roots is roughly proportional to the number of larvæ present.

AGRONOMIC AFFAIRS.

NOTICE OF ANNUAL MEETING.

The eleventh annual meeting of the American Society of Agronomy will be held in Baltimore, Md., on November 11 and 12, 1918; the hotel at which the meeting will be held will be announced later. Those who expect to present papers at this meeting are urged to send in titles promptly to the Secretary, Lyman Carrier, Department of Agriculture, Washington, D. C., so that the program can be planned and printed some weeks in advance of the meeting.

MEMBERSHIP CHANGES.

The membership reported in the May issue of the JOURNAL was 649. Since that time 3 new members have been added, making the present membership 652. The names and addresses of the new members, with a correction of a name previously published and such changes of address as have been reported, follow.

NEW MEMBERS.

ERDMAN, LEWIS W., Agr. Expt. Sta., College Park, Md.
HARLOW, H. C., Agr. College, Truro, N. S., Canada.
WILKINSON, J. V., 624 Egan St., Shreveport, La.

CORRECTION OF ADDRESS.

RUEDA, BUENAVENTURA, Linea 97, Antiguo Entre 8 y 10, Vedado, Habana, Cuba.

CHANGES OF ADDRESS.

ADAMS, E. L., Chico, Cal.
BELL, HENRY G., 1111 Temple Bldg., Toronto, Ont., Canada.
BREITHAUPT, L. R., R. R. No. 3, Payette, Idaho.
CHAPPELEAR, GEO. W., Normal Station, Harrisonburg, Va.
COWGILL, H. B., Box 333, Fort Smith, Ark.
DEATRICK, E. P., Kutztown, Pa.
FLORELL, VICTOR H., Plant Introduction Garden, Chico, Cal.
FRENCH, W. L., Austin, Minn.
JUSTIN, M. M., 442 State Capitol, Salt Lake City, Utah.
KENNEY, RALPH, Kansas State Agr. College, Manhattan, Kans.
LUSK, VIGGO, Dept. Plant Breeding, Cornell Univ., Ithaca, N. Y.
MARTIN, J. H., Harney Branch Station, Burns, Oreg.
MILNER, F. W., Hartford, Kans.

Moore, Harvey L., Leonard Apts., Bellevue & Prospect Sts., Trenton, N. J.
Newton, Robert, Woodstock, N. B., Canada.
Olson, P. J., R. F. D. No. 1, Grafton, N. Dak.
Osler, H. S., Court House, Ann Arbor, Mich.
Russel, J. C., Dept. Chem., Nebr. Wesleyan Univ., University Place, Nebr.
Shinn, E. H., 225 Main Street, Stillwater, Okla.
Thompson, G. E., Experiment Station, Tucson, Ariz.
Thompson, James, College of Pharmacy, U. of W., Seattle, Wash.
Warburton, C. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Woodard, John, Mt. Morris College, Mt. Morris, Ill.

ROLL OF HONOR.

The Society's honor roll of members who are serving their country in its military or naval forces is constantly growing. The list as here printed contains the names of 42 men, but no doubt it is quite incomplete. The editor will appreciate items of interest regarding any of these men, as well as corrections in or additions to the list. News items regarding commissions granted, citations, or other matters are particularly useful. The names so far reported follow.

Albert, A. R.,
Bliss, S. W.,
Brockson, W. I.,
Bruce, O. C.,
Brunson, A. M.,
Burnett, Grover,
Cates, Henry R.,
Chapman, James E.,
Childs, R. R.,
Deatrick, E. P.,
de Werff, H. A.,
Dickenson, R. W.,
Downs, E. E.,
Ellison, A. D.,
Freeman, Ray,
Gentle, G. E.,
Gilbert, M. B.,
Graham, E. E.,
Gray, Samuel D.,
Holland, B. B.,
Hudelson, R. R.,
Jensen, O. F.,
Kenworthy, Chester,
Kime, P. H.,
Macfarlane, Wallace,
Moomaw, Leroy,
Newton, Robert,
Palmer, H. Wayne,
Piemeisel, R. L.,
Purington, James A.,
Quigley, J. V.,
Ratcliffe, Geo. T.,
Raymond, L. C.,
Richards, Phil E.,
Schneiderhan, F. J.,
Schoonover, W. R.,
Scott, Herschel,
Smith, J. B.,
Starr, S. H.,
Tabor, Paul,
Towle, R. S.,
Westbrook, E. C.

NOTES AND NEWS.

Whitney J. Atcheson has been appointed assistant agronomist at the Maryland station.

Ross L. Bancroft, formerly associate professor of soils in the Iowa college, is now in charge of soil extension work in that State.

Percy B. Barker, recently head of the department of agronomy in the University of Arkansas, has been appointed assistant professor of agricultural education in the University of Minnesota.

H. G. Bell, for the past several years with the Chicago office of the American Fertilizer Association, is now in charge of the recently opened Canadian office of the association, at Toronto.

R. Page Bledsoe, formerly of the California station, is now in charge of forage crop work on the recently established station at Waterville, Wash.

H. B. Cowgill, formerly plant breeder of the Porto Rico station, is now in charge of the sorghum sirup investigations of the Department of Agriculture at Fort Smith, Ark.

R. H. Forbes, dean and director of the Arizona college and station, has been granted a year's leave of absence to assist the Société Sultanienne d'Agriculture of Cairo, Egypt, in agricultural war service in the Valley of the Nile.

E. J. Iddings, dean of the Idaho college of agriculture, has been made director of the Idaho station as well.

Robert Newton, formerly field husbandman for the province of New Brunswick, has been in active service in the Canadian army since July, 1915. He is now captain of E Battery, Canadian Anti-Aircraft Service, and is in France.

P. J. Olson, assistant in plant breeding at the Minnesota station, has resigned to engage in farming in North Dakota.

Everett P. Reed, assistant agronomist of the New York State station, has resigned to become a farm bureau agent in Ohio.

W. J. Spillman has resigned as chief of the office of farm management, U. S. Department of Agriculture, a position which he has held for the past sixteen years, to become editor of The Farm Journal, Philadelphia.

G. E. Thompson, formerly agronomist in the extension service in Kansas, is now agronomist of the Arizona station.

P. F. Trowbridge of the department of agricultural chemistry of the Missouri station has been elected director of the North Dakota station and entered on his new duties September 1. He succeeds L. Van Es, resigned to become head of the veterinary department in the University of Nebraska.

R. O. Westley of the Iowa college has been elected assistant professor and A. M. Christensen of North Dakota has been made instructor in farm crops at the Northwest School of Agriculture, Crookston, Minn., succeeding F. L. Kennard and O. M. Kiser, respectively.

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INTERPRETATION OF FIELD OBSERVATIONS ON THE MOISTNESS OF THE SUBSOIL.[1]

F. J. ALWAY, G. R. MCDOLE AND R. S. TRUMBULL.

INTRODUCTION.

Soil investigators and agronomists do not appear to have recognized at any time the possible practical importance of field observations on the moistness of the subsoil in dry-land regions as a guide to the more intelligent employment of various cultural operations. As the result of some limited field studies in Saskatchewan in 1904 and 1905, one of us suggested that in that province, where the summer fallow is very extensively employed, the ordinary farmer, provided with a 6-foot auger, could form a fair estimate of the moisture conditions of his fields before the spring was sufficiently advanced to allow seeding. He would thus be in position to decide intelligently whether to sow grain upon his stubble fields or to summer fallow them, instead of being governed by the rule of "one year of fallow followed by two years of grain" (1, p. 339).[2] It was suggested that all progressive dry-land farmers would eventually provide themselves with soil augers so that they might keep themselves informed as to the moisture conditions of their fields (2, p. 42). Later studies in western Nebraska and in the Southwest have made it evident that field observations might be of at least equally great practical importance in these dry regions (3, p. 699).

[1] The work reported in this paper was carried out in 1907 to 1913 while the authors were members of the staff of the Nebraska Agricultural Experiment Station. Received for publication April 6, 1918.

[2] References are to "Literature cited," p. 278.

In the ten years which have elapsed since the publication of these views, there has been no definite recognition of the practical importance of field observations, even by the agronomists of the many dry-land experimental substations in this country. The nearest approach to such recognition is contained in a very recent publication by Chilcott and Cole on "Growing Winter Wheat on the Great Plains," in which it is stated that "a good guide to practice is to sow a large acreage when the soil at seeding time is wet to as great a depth as 3 feet," and that "the depth to which the soil is wet can usually be told easily by inspection, the break between the wet and dry soil being very sharp" (9, p. 4). Regarding the method of inspection they make no suggestions.

Our soil moisture studies in the semiarid portion of Nebraska, in which we made notations on the moisture condition of each foot section of the subsoil as the samples were being taken and later determined both the moisture content and the hygroscopic coefficient (5), have provided data from which to attempt a quantitative interpretation of field observations. The use of the soil auger and a record of field observations upon the occasion of visits to various districts in the drier portions of this country and Canada have served to show that the matter may be of practical importance in all these places. In regions with a humid climate such observations are of much less importance. Thus studies carried out in eastern Nebraska at the same time as those in western Nebraska convinced us that in the former such observations have only a very limited field of usefulness, while later studies made in Minnesota indicate that here they are of still less value.

The moisture condition of a soil may conveniently be expressed by stating both the hygroscopic coefficient and the ratio of the water content to this. Thus, the expression, *hyg. coef.* = *10.0*, *ratio* = *1.7*, indicates a moisture content of 17.0 percent, a wilting coefficient of 15.0[3] (8, p. 65), 5.0 percent of free water, and 2.0 percent of growth water. As the ratios 1.0, 1.5, and 2.0–2.5 appear to indicate, respectively, the minimum to which crop plants can reduce the soil moisture, the point at which root penetration practically ceases (7, p. 278), and the water-retaining capacity of well-drained arable mineral soils (6, p. 69), such an expression makes all these relations apparent at a glance. The ratio when used alone indicates the relative moistness, while its combination with the hygroscopic coefficient expresses the moisture condition.

[3] The exact figure is 14.7.

Tools for Sampling Dry Subsoils.

Anyone who has become familiar with the use of the ordinary soil auger in exploring the subsoils of humid regions must be struck by the limitations of this tool when he first tries to employ it in the drier lands. Usually, as the auger is withdrawn from the hole the soil slides off and the loosened material, instead of being brought to the surface for inspection, accumulates in the bottom of the boring. At shallow depths, 2 or 3 feet, it is possible by means of a quick jerk of the auger to throw to the surface enough of the loosened subsoil to allow its examination for the purposes of the ordinary soil survey, and by repeating the operation the hole may from time to time be thus cleaned sufficiently to allow the successive levels to be inspected. With increasing depth this device becomes less and less applicable, and is quite useless long before the tenth foot has been reached. It is evident that satisfactory samples of the subsoil can not be taken by any tool that will not permit the withdrawal of the loosened portion without admixture with material from nearer the surface. For exploration purposes this difficulty may be met by carrying along a can of water and from time to time pouring some of it down the hole, the loosened subsoil so moistened being removable without difficulty. This may aid in obtaining samples for chemical analysis, but not for moisture determinations.

The soil tubes invented by King and improved by Briggs allow satisfactory sampling to a depth of 10 feet wherever coarser rock fragments are absent. Even longer tubes may be employed, but the extreme inconvenience of these, especially when they must be carried from place to place, will be evident. A serious objection to the use of soil tubes lies in the inability of the operator to observe the differences in moisture content as the samples are being taken.

A very convenient tool for use at a distance from the laboratory is the sleeve auger or "auger with casing" which Tinsley (10, p. 57) devised soon after he began his soil studies in New Mexico. The essential feature of this is a metal sheath or sleeve which slides down over the bit; as the auger is withdrawn from the boring the loosened material is forced tightly into the sheath and so brought to the surface. By means of this tool samples satisfactory for both chemical and moisture determinations may be taken from the driest subsoil and from any depth. When provided with 2- or 3-foot extensions, it may, like the ordinary auger, be extended to any desired length, and also used without the sheath, if the latter is made removable. In very

dry soils the sleeve is necessary, but in moist soils it is very inconvenient, while between these two conditions there is a stage of moistness in which both the open and the sheathed bit do satisfactory work, although more rapid headway can be made with the former. The complete field equipment for field observations where dry subsoils are involved includes three augers, each 3 feet long, two of them open and of different diameters, the third with a sleeve and of the same diameter as the smaller of the other two. In addition three handles, two small pipe wrenches, some files, and sufficient 3-foot extensions to reach any depth desired are needed. Sufficient tools to sample to a depth of 20 feet can be carried by hand conveniently in a 3-foot case.

Methods of Sampling.

The purpose of our record of field observations was threefold. In the first place they served to guide the one of us who was doing the sampling, our interest in learning the extremes of moistness found under any given tillage or crop condition being much greater than in ascertaining merely the average moisture conditions. To obtain sets of samples representative of the extremes we often first explored a field without taking samples, later deciding from the notations thus secured where and from what depths to collect the samples to be sent to the laboratory.

In the second place, when only one of us was in the field, these notes served to keep the workers at the laboratory in close touch with the field conditions. Long in advance of the arrival of the samples the men at the laboratory had a far better idea as to the actual moisture conditions being encountered in the field than otherwise would have been possible until after the samples had been dried and subjected to the hygroscopic coefficient determination. The tediousness of the latter is such that under our working conditions many months often elapsed between the taking of the samples and the determination of this value. The indirect method of Briggs and Shantz (8) for obtaining the hygroscopic coefficient from the moisture equivalent was developed by these authors only near the close of our work in Nebraska and even then, had the rather elaborate and costly equipment required been at our disposal, almost as much delay would have been caused as was the case with the direct method. The simpler and more expeditious indirect method, based upon a determination of the hygroscopic moisture (4, p. 351), had not then been developed, it being an outgrowth of our moisture studies.

Lastly, we had it in mind to attempt a numerical interpretation

whenever our data had become sufficiently numerous. This last purpose, however, was subordinated to our real object in the collection of samples, the determination of the relation of the extremes of moisture content to the hygroscopic coefficient. That our main purpose conflicted more or less with the third object mentioned will be pointed out in a later paragraph.

Field Notations.

The notations as to the relative moistness of the soil, made as the samples were being taken, were indicated by the letters *P, I,* and *M* for "powder," "intermediate," and "moist," respectively. The sleeve was employed only where a sample could not be obtained without it; in such cases the field notation was "P." Where the soil adhered so firmly to the bit that it could be removed from the hole by the ordinary auger without difficulty the condition was recorded as "M." Throughout the work we attempted to distinguish several intermediate degrees of moistness, such as "slightly moist" and "very slightly moist," but as we have found no definite concordance of these

Table 1.—*Relation of field notations to moisture condition in different portions of 12-inch sections, illustrating the difficulty of assigning a satisfactory notation to the foot section as a whole when an abrupt change occurs within it. All the borings were made in a small cornfield on the same day.*

Boring.	Depth, inches.	Field notation.	Ratio.	Hygroscopic coefficient.
1	25–28	M	1.7	
	29–36	P	1.1	
	Av. 25–36	—	1.3	[a]10.0
2	13–14	M	1.8	11.4
	15–24	I	1.5	10.0
	Av. 13–24	—	1.5	—
3	13–21	M	1.8	11.5
	22–24	P	1.2	10.4
	Av. 13–24	—	1.6	—
4	13–22	M	1.9	
	23–24	P	1.3	
	Av. 13–24	—	1.8	[a]11.2
5	13–21	M	1.7	
	22–24	P	1.2	
	Av. 13–24	—	1.6	[a]10.7
6	13–22	M	1.8	
	23–24	P	1.2	
	Av. 13–24	—	1.7	[a]10.9
7	13–18	M	1.8	
	19–24	I	1.5	
	Av. 13–24	—	1.6	[a] 8.9

[a] The two portions of the foot section had been combined before the hygroscopic coefficient was determined.

differences with the differences in the ratio of moisture content to hygroscopic coefficient we have, for the present purpose, included all of them under the designation "I." It was found that at certain stages of dryness the diameter, etc., of the bit employed seemed to determine whether a soil would slip off, and so be designated "P," or barely adhere when the auger was carefully withdrawn from the boring, and so be indicated as "I." The samples, except where otherwise indicated, were composites from 3 borings made 10 to 20 feet apart.

TABLE 2.—*Field notations on moisture conditions of samples from the three borings used in preparing field composites in representative fields, illustrating the difficulty of assigning a satisfactory notation to composites from sections differing distinctly in moistness.*

Field.	Boring.	Field notations		
		First foot.	Second foot.	Third foot
A	1	M	Upper half, M; lower half, P	P
	2	M	do.	P
	3	M	do.	P
	Section	M	I	P
B	1	M	P	P
	2	M	First 3 in., I; next 9 in., P	P
	3	M	I	I
	Section	M	I	I
C	1	M	First 3 in., I; next 9 in., P	P
	2	M	P	P
	3	M	I	First 3 in., I; next 9 in., P
	Section	M	I	I
D	1	M	M	First 6 in., M; next 6 in., I.
	2	M	M	First 6 in., I; next 6 in., P.
	3	M	M	First 3 in., I; next 9 in., P.
	Section	M	M	I

Where at any particular depth the soil in all three borings appeared equally moist the notation to be assigned was evident, but where there were distinct differences the field description was more complicated. Where the upper part of a foot section was moist and the lower "powder," or where the reverse held true, the condition of the whole section was recorded as "I." Where the greater part of the section was moist the ratio would be high, but where the opposite was found the ratio might prove low. This is illustrated by Table 1, in which data are reported from individual borings in which the foot sections showed a sharp break and were separated into two parts for

the moisture determination. The third foot of boring 1 showed a ratio of only 1.3 and the second foot of boring 4 a ratio of 1.8, although both were recorded as "I." In both cases the upper part of the foot was moist and the lower "powder," the ratios in the upper part being 1.7 and 1.9, respectively, and in the lower 1.1 and 1.3.

The matter was still further complicated by the use of composites, for the reason that the depth to which the subsoil had been moistened or dried out varied more or less from place to place and commonly we did not find in any field a uniformly constant depth. The notations on the samples taken from four fields in May, 1912, illustrate this (Table 2). The samples used for the moisture determinations were composites of the whole foot section from 3 borings, but on the foot section of each boring we made separate notations. To have obtained all the data possible for the interpretation of these field notations would have required separate determinations of moisture content and hygroscopic coefficient on 10 samples from the second foot of Fields A, B, and C, instead of on only the three. This was a case where the third of the above-mentioned purposes in making field notations had to be subordinated to the main object of the work.

Concordance of Notations with Actual Moistness.

Table 3 gives a summary of the data on over a thousand samples from Nebraska, 857 from the southwestern semiarid portion, and 235 from near Lincoln in the eastern humid portion. Of the 587 samples recorded in the field as "P" only 2 percent showed a ratio of 1.5 or 1.6 and none as high as 1.7, while a ratio of less than 1.4 was shown by 95 percent of those from western and by 90 percent of those from eastern Nebraska. Of the samples with the notation "M," 87 percent of those from the western and 91 percent of those from the eastern part of the State showed a ratio above 1.5. Thus approximately 95 percent of those recorded as *M* had a ratio of 1.5 or above and a similar percentage of those recorded as *P* had a ratio of less than 1.4. Thus, 1.5,[4] the computed wilting coefficient of Briggs and Shantz, may be regarded as the approximate dividing point, the soil being readily recognizable as *M* if it is much moister than this and as *P* when it is appreciably drier. This would lead to the conclusion that when sections uniform in moistness are noted as "I" they should be in a moisture condition approximating the ratio 1.5. While all the samples from the eastern part of the State and most of those from the western, 709 out of 857, had a hygroscopic coefficient

[4] To be accurate, 1.47 (8, p. 65).

of 5.0 or above, the number of the coarser-textured soils, 148, is sufficient to indicate that this property is not dependent upon a fine texture.

We have too few data on very fine-textured soils, those with hygroscopic coefficients of 16 to 25, and on the coarser sands, to decide whether or not these differ from the common tillable soils represented in Table 3.

TABLE 3.—*Relation of field notations to the actual moistness, expressed as the ratio of moisture content to hygroscopic coefficient.*

WESTERN NEBRASKA.

Field notation.	No. of samples.	Percentage of samples with ratio of								
		0.9 or lower.	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7 or higher.
(a) Finer textured soils, hyg. coef. 5.0 or higher.										
Powder.....	472	23	28	30	11	5	1	1	1	0
Moist.....	110	0	0	0	0	3	0	8	11	78
Intermediate	127	0	2	7	23	20	13	10	8	17
(b) Coarser textured soils, hyg. coef. below 5.0.										
Powder.....	63	13	22	29	21	1	8	3	0	3
Moist.....	53	0	0	0	0	2	10	8	4	76
Intermediate	32	0	0	6	0	3	3	22	25	41
(c) All soils sampled. Sum of a and b.										
Powder.....	535	22	27	30	11	5	2	2	1	0
Moist.....	163	0	0	0	0	2	3	8	9	78
Intermediate	159	0	1	7	20	17	11	13	11	20

EASTERN NEBRASKA.

Powder.....	52	2	4	28	30	27	6	2	2	0
Moist.....	128	0	0	0	0	1	1	7	5	86
Intermediate	55	0	0	0	11	13	22	22	10	22

While the degree of moistness of the subsoils corresponding to the field notation "P" thus appears to be similar in both the semiarid and humid portions of Nebraska, the frequency of occurrence of this dry condition shows a great difference. While in the former it appears to be the prevailing condition of the subsoil, being found in prairies, abandoned lands, alfalfa fields, grain fields after harvest, and at times even in clean cultivated orchards where the trees are still alive and in a fairly healthy condition, in the latter it is rarely found except in the subsoil of well established alfalfa fields.

The various levels of the subsoil have the condition *M* replaced by *P* only through the action of plant roots which have actually penetrated into them. In the semiarid districts those portions of the subsoil found to be *P* when a crop has died of drought, suffered serious injury from lack of water, or matured in a period of rather dry weather, but which previously, either at the time of seeding or sub-

TABLE 4.—*Moisture conditions in fields near Imperial, Nebr., in April, 1911, illustrating relative value of field notations compared with the actual determination of total moisture as an index of the available moisture after a prolonged drought.*

FIELD NOTATIONS.

Depth, feet.	Prairies.		Sorghum stubble.	Corn stubble.					Wheat stubble.		Winter wheat.
	1.	2.		1.	2.	3.	4.	5.	1.	2.	
1	P	P	M	P	P	I	P	M	P	P	P
2	P	P	I	P	P	I	P	I	P	P	I
3	P	P	I	P	P	I	P	I	P	P	I
4	P	P	I	P	Rock	I	P	I	P	P	I
5	P	P	I	P	—	I	P	I	I	P	I
6	P	P	I	P	—	I	P	I	I	P	I

TOTAL WATER.

	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	5.4	2.3	4.6	6.9	7.8	5.2	5.6	8.3	11.0	6.8	4.6
2	7.5	2.4	6.0	9.4	10.8	9.8	7.7	7.0	10.9	8.1	6.5
3	7.0	2.2	5.4	10.3	9.5	9.1	8.2	5.6	9.6	8.0	6.2
4	6.1	2.4	4.1	9.7	—	10.0	9.1	10.2	10.9	8.9	4.3
5	4.2	2.2	8.6	7.6	—	7.0	4.6	10.5	19.8	9.8	3.4
6	4.0	2.3	8.6	7.1	—	5.3	7.8	9.9	16.8	7.4	5.9
Av.	5.7	2.3	6.2	8.5	—	7.7	7.2	8.6	13.2	8.2	5.2

HYGROSCOPIC COEFFICIENTS.

1	6.4	2.0	2.9	6.8	7.7	3.5	6.0	4.7	13.2	6.4	3.2
2	7.9	2.2	4.3	9.3	10.2	7.7	7.3	4.4	11.5	7.9	4.1
3	8.1	2.0	4.3	9.6	8.5	6.9	7.6	3.8	9.6	8.1	4.1
4	6.8	2.0	3.0	9.5	—	8.0	8.4	6.2	9.8	9.2	3.2
5	4.2	2.1	6.4	7.2	—	8.5	4.0	6.2	14.9	9.6	2.2
6	3.9	2.0	7.1	6.4	—	3.6	6.1	5.3	12.4	7.1	3.5
Av.	6.2	2.1	4.7	8.1	—	5.8	6.6	5.1	11.9	8.1	3.4

RATIOS.

1	0.8	1.1	1.6	1.0	1.0	1.5	0.9	1.8	0.8	1.1	1.4
2	0.9	1.1	1.4	1.0	1.1	1.3	1.1	1.6	0.9	1.0	1.6
3	0.9	1.1	1.3	1.1	1.1	1.3	1.1	1.5	1.0	1.0	1.5
4	0.9	1.2	1.4	1.0	—	1.2	1.1	1.6	1.1	1.0	1.3
5	1.0	1.0	1.3	1.1	—	1.3	1.1	1.7	1.3	1.0	1.5
6	1.0	1.1	1.2	1.1	—	1.5	1.3	1.9	1.4	1.0	1.7
Av.	0.9	1.1	1.3	1.0	—	1.3	1.1	1.7	1.1	1.0	1.5

TABLE 5.—*Moisture conditions at Imperial, Nebr., in May, 1912, illustrating the reliability of field notations after a wet winter following a very dry summer.*

FIELD NOTATIONS.

Depth, feet.	Prairies.						Corn stalks.				
	1.	2.	3.	4.	5.	6.	1.	2.	3.	4.	5.
1	M	M	M	M	M	M	M	M	M	M	M
2	I	M	M	M	M	M	M	M	I	M	M
3	P	M	M	I	P	M	P	M	P	I	M
4	P	M	M	P	P	P	P	M	P	P	I
5	P	M	M	Rock	Rock	P	P	M	Rock	Rock	I
6	P	M	M	—	—	P	P	M	—	—	I

TOTAL WATER.

	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	16.0	4.0	7.6	16.9	12.2	7.8	17.5	8.6	18.3	17.3	14.0
2	16.9	5.4	10.3	18.0	14.8	11.1	17.8	8.7	17.8	17.5	12.8
3	11.2	7.9	9.4	15.0	9.2	10.9	13.1	8.5	10.7	13.6	9.5
4	6.5	6.9	8.0	10.1	6.1	4.2	12.0	10.0	10.4	10.2	8.2
5	5.5	5.9	4.9	—	—	3.7	10.5	15.6	—	—	9.8
6	5.1	6.1	4.4	—	—	3.6	6.9	21.3	—	—	9.0
Av.	10.2	6.0	7.4	—	—	6.9	13.0	12.1	—	—	10.5

HYGROSCOPIC COEFFICIENTS.

1	8.2	1.6	2.6	7.1	5.8	3.2	7.1	2.4	7.2	7.1	5.5
2	10.2	2.6	3.7	7.5	6.3	3.2	8.3	2.6	9.6	9.2	5.9
3	8.9	1.9	3.5	9.7	7.1	5.4	9.4	2.6	9.5	8.7	4.4
4	5.3	1.5	3.5	9.0	5.1	3.7	10.0	3.0	7.0	7.0	3.7
5	4.7	1.3	1.6	—	—	3.4	7.8	5.6	—	—	4.9
6	4.9	1.3	1.3	—	—	3.0	4.5	9.3	—	—	4.6
Av.	7.0	1.7	2.7	—	—	3.7	7.9	4.2	—	—	4.8

RATIOS.

1	2.0	2.5	2.9	2.4	2.1	2.4	2.5	3.6	2.5	2.4	2.5
2	1.7	2.1	2.8	2.4	2.3	3.5	2.1	3.3	1.9	1.9	2.2
3	1.3	4.2	2.7	1.5	1.3	2.0	1.4	3.3	1.1	1.6	2.2
4	1.2	4.6	2.3	1.1	1.2	1.1	1.2	3.3	1.5	1.5	2.2
5	1.2	4.5	3.1	—	—	1.1	1.3	2.8	—	—	2.0
6	1.0	4.7	3.4	—	—	1.2	1.5	2.3	—	—	2.0
Av.	1.4	3.8	2.9	—	—	1.9	1.7	3.1	—	—	2.2

sequently, had been found in the condition *M*, may be expected to show a ratio not far from 1.1. On the other hand, if this portion of the subsoil had not been in the state *M* at any time since the crop was planted, and so not in a condition to permit of root penetration, the condition *P* found at its maturity or death may correspond to a ratio as high as 1.5, it being that induced by some preceding crop which

had matured under more favorable conditions of moisture supply in the surface layers.

TABLE 6.—*Moisture conditions in prairies near McCook and Wauneta, Nebr., in the spring of 1911.*

Depth, foot.	Field notations.				Total water.			
	McCook.		Wauneta.		McCook.		Wauneta.	
			April 4.				April 4.	
	March 24.	March 25.	Sample 1.	Sample 2.	March 24.	March 25.	Sample 1.	Sample 2.
					Pct.	*Pct.*	*Pct.*	*Pct.*
1	P	P	P	P	7.8	7.3	8.4	8.8
2	P	P	P	P	8.3	8.8	7.8	8.5
3	P	P	P	P	7.8	8.7	8.4	9.0
4	P	P	P	P	7.8	8.3	9.8	8.4
5	P	P	P	P	8.4	8.3	12.9	7.5
6	P	P	I	P	8.9	8.5	10.4	7.5
7	P	P	I	P	8.8	8.5	9.7	7.3
8	P	P	I	P	9.3	9.1	8.7	7.3
9	P	P	I	P	9.3	9.3	7.6	7.5
10	P	P	M	P	9.5	9.2	6.8	7.6
11	P	P	M	P	9.6	9.0	6.6	8.3
12	P	P	M	P	9.5	9.3	6.7	8.2
13	—	—	M	P	—	—	6.8	7.8
14	—	—	M	P	—	—	7.0	7.3
15	—	—	M	P	—	—	8.9	7.8
	Hygroscopic coefficient.				Ratios.			
	Pct.	*Pct.*	*Pct.*	*Pct.*				
1	9.6	8.7	8.7	9.0	0.8	0.8	1.0	1.0
2	10.5	10.1	9.2	9.6	0.8	0.9	0.8	0.9
3	9.1	9.6	9.1	10.9	0.9	0.9	0.9	0.8
4	8.3	9.0	9.2	10.0	0.9	0.9	1.1	0.8
5	8.1	8.6	9.6	8.8	1.0	1.0	1.3	0.9
6	8.1	9.0	8.3	7.7	1.1	0.9	1.2	1.0
7	8.1	7.9	6.6	6.7	1.1	1.1	1.5	1.1
8	8.3	8.6	5.7	7.3	1.1	1.1	1.5	1.0
9	8.1	8.4	4.9	7.0	1.1	1.1	1.5	1.1
10	8.1	8.4	4.4	7.0	1.2	1.1	1.5	1.1
11	8.1	8.6	4.0	7.9	1.2	1.0	1.6	1.0
12	8.1	8.6	3.7	7.4	1.2	1,1	1.8	1.1
13	—	—	4.3	6.6	—	—	1.6	1.2
14	—	—	4.2	6.5	—	—	1.7	1.1
15	—	—	5.1	6.4	—	—	1.7	1.2

Tables 4, 5, and 6 illustrate to what extent such field observation may afford reliable information. The notations reported in the first part of each table are the record entered in our field note books as the samples were taken, while the corresponding data on hygroscopic coefficient and ratio were first secured some weeks, or at times many months, later. It will be seen that the field notes afforded immediately a reliable basis for further rational sampling for the purposes we had in view.

Practical Applications.

From the preceding data it is evident that in the semiarid portions of Nebraska, a field examination with an auger without any collecting and drying of samples will permit a rather close estimate of the amount of useful moisture in the subsoil, especially where the latter is comparatively uniform in texture and its hygroscopicity is known. A still finer interpretation of the field observations is facilitated by a knowledge of the previous moisture condition, the character of the preceding weather, and the cultural history of the fields concerned.

To illustrate the application let us assume the case of a farmer on loess soil near Wauneta or McCook, who, during a period such as that of 1909–1913, makes use of a 6-foot auger. If at planting time he find both soil and subsoil moist to the full depth of the auger he may sow his seed with the assurance that there is moisture enough, independent of any rainfall, to ensure the growth, or possibly even the maturity, of small grains. If in both soil and subsoil he find only "P" he will foresee that any crops then planted will be entirely dependent upon the rains to follow, while if the surface soil be *M* and the subsoil *P* the seed will germinate but the survival of the plants will be uncertain. Lastly, if the subsoil be *M* and only the surface layer *P* he need await only a rain sufficient to moisten this surface layer. In the case of certain cultivated and garden crops planted in hills he may add enough water to the hill to moisten a very small area from the surface down to the moist subsoil, so that the roots may develop down into the latter and draw upon it for their supply of moisture, the remaining portion of the dry surface layer, that between the hills, being no serious handicap.

If after harvesting the crop or at the time of plowing he find *P* to extend to a depth of 6 feet, and later, after a period of wet weather, find *M* to replace it to a depth of 4 feet, he may safely assume that through the 4 feet the moisture content is from 2.0 to 2.4 times the hygroscopic coefficient. Further, as the latter value in the case of the loess subsoil averages approximately 9.0 and the texture is quite uniform, he may even compute the weight per acre of the maximum amount of available water accessible to the roots of the crops he may plant.

In preparing land for an orchard or tree plantation he would practice clean cultivation or flood it by directed storm-waters until the condition *M* is established to a depth of from 3 to 6 feet. If in a grove or orchard already well established the trees ceased to thrive and he found *I* or *P* a persistent condition of the subsoil he would

prepare against the next tree-killing, dry series of years by a severe pruning of his trees, or still better by a thinning of the stand.

Condition of "Powder" of Wide Occurrence in Dry-Land Regions.

Numerous sets of samples from nonirrigable lands in New Mexico and Arizona indicated a similar relation of the ratio to the field notations, *P* being even much more prevalent in those States than in western Nebraska.

In field observations unaccompanied by moisture determinations we have found the dry condition *P* to occur very widely on the drier lands of this country and Canada, and might specifically mention Akron and Parker, Colo.; Dalhart and Amarillo, Texas; Great Falls, Forsyth, and Hobson, Mont.; Ritzville and Prosser, Wash.; Pendleton and Echo, Oreg.; Modesto, Clovis, and Delano, Cal.; Indian Head and Moose Jaw, Sask., and Lethbridge, Strathmore, and Medicine Hat, Alta.

In more humid districts, such as Minnesota, the very dry condition indicated by "P" appears to be even more infrequent than in eastern Nebraska, and hence the field observations of less importance.

Summary.

At the time of taking a large number of samples of soil for moisture determinations, both in semiarid southwestern Nebraska and in the humid eastern portion of the same State, notations were made as to their apparent moistness and from the correlation of these with data later obtained in the laboratory it has been found possible to give the field notations a numerical interpretation, most conveniently expressed as the ratio of the moisture content to the hygroscopic coefficient. When the soil was too dry to be removable from the boring by the ordinary open auger, a condition designated as "powder" or "P," the ratio was 1.3 or lower, whereas when it was moist enough to adhere well to the bit it showed a ratio of 1.5 or above.

In the case of the semiarid soils dealt with, which had hygroscopic coefficients ranging from 2.0 to 14.0 and so represent the common tillable types, the dry condition indicated by "P" was found to be very common. With these the mere field examination with the ordinary soil auger, without any weighing or drying of samples, enables a quite satisfactory estimate of the moistness. Data on very fine-textured soils and on coarse sands were too few to decide whether the field notations on these may be interpreted in the same manner.

With the humid soils the dry condition represented by "P" was

found comparatively rare, being confined chiefly to well established alfalfa fields, and hence in such districts the field notations have only a limited usefulness.

The ordinary mineral subsoils rarely show a ratio above 2.5, roots appear to be unable to penetrate a soil stratum in which the ratio is below 1.5 (i. e., P), and the lower limit to which plant roots can reduce the subsoil moisture is approximately 1.0 or 1.1. Therefore the above method of interpretation gives promise of usefulness in dry-land regions, not only as a convenient field aid for soil investigators and agronomists, but also as a practical method for the county agricultural agents and the more intelligent farmers.

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HASTENING THE GERMINATION OF BERMUDA GRASS SEED BY THE SULFURIC ACID TREATMENT.[1]

W. E. Bryan.

Bermuda grass seed is one of the most difficult of all agricultural seeds to germinate. The ordinary blotter method used for germinating such seeds as alfalfa, corn, beans, wheat, etc., gives no results whatever in most cases. Samples sent to the Arizona station from time to time for germination have given rise to the necessity of ascertaining a reliable method for their germination which would give conclusive results in a shorter period than 21 days, the time usually allowed for the germination of these seeds.

The use of sulfuric acid in hastening the germination of seeds having hard and impervious seed coats is well known. The possibility that the slowness of the germination of Bermuda grass seed was likewise due to an impervious seed coat has suggested that a similar treatment with sulfuric acid might also hasten their germination. To test this suggestion the following experiment was carried out.

A sample of Bermuda grass seed from one of the local seed houses was obtained and 12 lots were counted out, each containing 200 seeds. Each lot was treated with sulfuric acid for periods varying from 5 minutes for the shortest time to 60 minutes for the longest time. In treating the seeds each counted lot was placed in a small glass dish and enough sulfuric acid poured over to cover them. A glass rod was used to stir the acid so that all seeds would be quickly immersed. At the end of each treatment the dish containing the seeds and the acid was dipped into a large beaker of water, and the seeds washed into a cambric bag so that the acid was quickly drained away. The bag was then placed under a faucet and allowed to wash for at least 5 minutes so that all trace of the acid was removed. The bag was then turned wrong side out and the treated seeds were spread on an open blotter for germination. This is conveniently arranged by tying a piece of blotting paper over the top of a small circular glass dish about 2½ inches in diameter, the edge of the paper being pressed down the vertical side of the glass dish so that it reaches almost to the bottom and securely tied with a string. This provides a flat surface on top of the circular dish where the seeds are spread

[1] Contribution from the Arizona Agricultural Experiment Station, Tucson, Ariz. Received for publication April 8, 1918.

out. The germinator is then placed in a larger vessel about 5 inches in diameter and about a half inch of water is poured into the larger vessel. The water soon spreads to all parts of the blotter, thus keeping the seeds in contact with a free water surface without excluding the atmosphere from them. The large vessel is then covered and placed in the germinating chamber, where the temperature is kept at 35° F. during the day and permitted to drop down to room temperature during the night. Plate 7, figure 1, shows the blotter as used in these germinations.

The number of seeds germinating in each sample was counted out and recorded every two days throughout the experiment. Table 1 summarizes the results obtained and gives the total germination on the dates indicated at the heads of the columns.

TABLE 1.—*Germination of Bermuda grass seed treated with sulfuric acid for periods of varying length.*

Sample No.	Time treated, minutes.	Total percentage germinated at each reading.					
		Second day.	Fourth day.	Sixth day.	Eighth day.	Twentieth day.	Twenty-second day.
1	5	1	51	53	54	54	54
2	10	1	68	71	71½	71½	71½
3	15	2½	64	69½	71½	71½	71½
4	20	9	64	66	69	70	70
5	25	9½	36	46	49	51½	51½
6	30	5	27	31½	31½	33	33
7	35	3½	10	22½	22½	24	24
8	40	2	12	19	19	19	19
9	45	0	2	9	14½	16½	16½
10	50	0	1	3½	6	6	8½
11	55	0	1	5	6½	6½	7
12	60	0	2	5	9½	11	11½

In comparison with the above, the highest germination from five untreated lots was 4½ percent on the tenth day, 16 percent on the fifteenth day, and 22½ percent on the twenty-first day.

Table 1 shows:

1. That the lot treated for 10 minutes gives the quickest germination in quantities sufficiently large for obtaining comparative results.

2. That samples treated from 10 to 20 minutes give approximately the same germination in four days, and that these samples run fairly close throughout the entire germinating period.

3. That 95 percent of the total germination of sample No. 2 was obtained at the end of the fourth day.

4. That the highest percentage of germination obtained from any one of the untreated lots was 22½ percent in 21 days.

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FIG. 1. Blotters in damp chambers as arranged for germination of Bermuda grass seed.

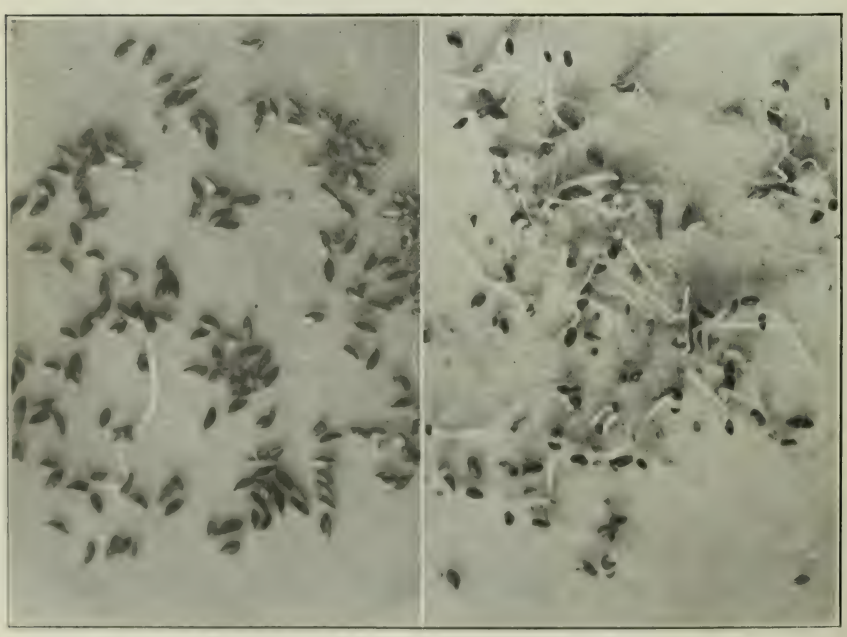

FIG. 2. Bermuda grass seed four days after setting for germination; at the left, untreated, 1 percent germinated; at the right, treated for 10 minutes, 68 percent germinated.

Plate 7, figure 2, shows the results of germination after four days in an untreated lot and in a lot which was treated for ten minutes. The untreated lots germinated only 1 percent, while the lot which had been treated for 10 minutes had germinated 68 percent.

It therefore seems that this method may be used to considerable advantage in saving time in making germination tests. As 95 percent of the seeds are germinated in four days by this treatment, and only 22½ percent were germinated in the untreated sample at the end of 21 days, it seems possible by this method to get a better estimate of the viability of the seeds in four days than with untreated seeds which have run throughout the entire period usually allotted by seed analysts to the germination of Bermuda grass seed.

THE DECOMPOSITION OF ORGANIC MATTER IN SOILS.[1]

FRED G. MERKLE.

INTRODUCTION.

OCCURRENCE OF CARBON COMPOUNDS.

Carbon compounds are universally distributed in all agricultural soils. They are ever being produced and consumed in the natural cycle of the element. The sources of gain in relation to soils are:

1. By bacteria;
2. By green plants;
3. By rains and snows;
4. Absorption of the gas;
5. Rise of carbon dioxide from below.

1. Bacteria are usually regarded as liberators rather than fixers of the element carbon, yet species have been isolated which perform the latter function. Kaserer (15)[2] demonstrated the production of organic matter by bacteria growing in inorganic media in an atmosphere containing carbon and hydrogen. The work was confirmed by Nabokish and Lebendeff (28), who showed the disappearance of hydrogen and carbon accompanying their fixation.

2. It is generally, not universally, assumed that green plants take all their carbon from the air. Thus a green crop plowed under will add 300 to 1,000 pounds of organic matter per acre (dry basis) or

[1] Thesis submitted for the degree of M.Sc., Massachusetts Agricultural College, Amherst, Mass., June, 1917. Received for publication March 3, 1918.

[2] Numbers in parentheses refer to "Literature cited," p. 300.

approximately 0.04 percent. Green plants are, undoubtedly, the greatest source of gain, yet the amount is small in relation to that already existing in the soil. Even poor soils may contain 60,000 pounds per acre.

3. Rains and snows wash CO_2 from the air, probably combined with NH_3 as ammonium carbonate. Schumacher (38) gives the CO_2 content of rain water as 0.3 to 1.0 volume in 1,000 of rain. Thus, a region having a 36-inch rainfall would annually receive from 400 to 1,500 cubic feet or from 50 to 175 pounds of CO_2. Such a figure seems very small, yet it helps to compensate the numerous losses.

4. Soils have an absorptive power for gases, especially carbon dioxide and ammonia. Ferric hydrate, alumina hydrate, humus, and clay appear to be the most active soil constituents as regards absorption of CO_2. Reichardt and Blumtritt (34) determined the volume of gas absorbed by equal volumes of various substances and the percentage of CO_2 contained as follows:

Material.	Total gas absorbed by 1,000 grams.	Percent CO_2 by volume.
Charcoal	164	0
Peat	102	51
Garden soil	14	33
$Fe(OH)_3$	375	70
Fe_2O_3	39	4
$Al(OH)_3$	69	59
Clay, moist	29	34
Silt	40	32
$MgCo_3$	729	29
$CaSO_4 \cdot 2H_2O$	17	0

The constituents found abundant in clay, viz., iron and alumina as hydrates, show a strong absorptive power for CO_2. Peat is relatively high. Von Dobeneck (42) obtained the following results:

Material.	CO_2 absorbed.
Quartz, 100 grams	0.023 gram
Kaolin, 100 grams	0.261 gram
Humus, 100 grams	1.773 grams
$Fe(OH)_3$, 100 grams	5.054 grams

If we let quartz represent sand and kaolin clay and combine the results of Reichardt and Blumtritt with those of von Dobeneck it is safe to conclude that the soil's absorptive capacity for CO_2 is largely due to its clay and humus content and to the state of its iron compounds.

To show that soils actually do take on carbon by absorption the

results of Lemmermann (22) may be cited. He allowed a kilogram of soil to incubate for a period of eight weeks, determining the total carbon at the beginning and end of this period. An increase of 0.33 gram was observed in one instance and 0.02 gram in another.

5. Many carbon-containing deposits exist within the earth's crust. Just how much carbon may come to the surface from these deposits can not be determined, but it is probable that methane produced below may gradually rise to the surface and upon reaching better aerated conditions, be oxidized to CO_2. The deeper soil layers contain greater quantities of CO_2 than the surface layers. Ebermayer (8) gives the following figures at 15 and 70 cm. respectively:

Location.	CO_2 content at different depths. At 15 cm.	At 70 cm.
Beech woods	0.62 per cent.	1.19 per cent.
Pine woods	1.13 per cent.	9.39 per cent.
Moss	1.93 per cent.	7.98 per cent.
Sod	.60 per cent.	4.13 per cent.
Bare ground	1.19 per cent.	7.02 per cent.

Pfeffer (29) gives the CO_2 content of the soil air at a depth of 6 meters as 8 percent or more.

While it is possible that the increased amount of carbon dioxide in the lower layers is due to the downward flow of the gas, it is more probable that it is diffusing up from below, in which case it would be an additive agent.

SOURCES OF LOSS OF CARBON FROM SOILS.

Soils may lose carbon (1) through leaching, (2) through evolution of CO_2, and (3) through possible removal by crops.

That soils under certain conditions decrease in organic content is frequently observed. Walker (43) reports a decrease in humus content on nonrotated fields as follows:

Crop.	Percent humus. 1895.	1905.	Difference.
Corn continuous	3.23	2.96	— 0.27
Mangels continuous	3.03	2.86	— 0.18

Rotated fields and fields growing legumes continuously showed a slight gain in the ten-year period.

Mooers, Hampton, and Hunter (27) show that only when the crop is removed can a decrease in humus content be expected.

1. *Loss through Leaching*—Soils have a strong absorptive power for organic matter; therefore, little or no carbon is lost in that form. The small amount of organic matter soluble in the presence of soil

was shown by Sutton (40). He analyzed the surface water of cultivated fields and found it to contain but 0.4 part of organic matter in 100,000, a seeming insignificant amount. If organic matter were subject to loss by leaching we would expect the subsoil of a continuously manured plot to contain more carbon than that of a nonmanured plot. Such is not the case. Dyer (7) shows that the subsoil of a plot manured for 50 years contains no more, even less, carbon than that of a plot undunged for 41 years. The difference is within the limit of error.

Condition.	Carbon in third 9-inch layer of soil.
Dunged 9 years, undunged 41 years	0.515 per cent.
Dunged 50 years	0.492 per cent.

To be capable of leaching, organic matter must be soluble and when in solution it is easily precipitated by bases.

Carbon as bicarbonate of lime is easily lost, as is shown by frequent analyses of drainage waters from limed fields (12).

2. Some carbon may be lost through evolution of CO_2, but if any the amount must be slight.

3. To say that plants may remove carbon from the soil may seem contrary to our teachings, yet there are numerous evidences that plants may derive a part, at least, of their carbon through their roots.

It has been observed at the Rothamstead station that poor crops of wheat due to unfavorable climatic conditions have higher percentages of ash elements than good crops. Hence minerals do not seem to be limiting factors. Cameron (4) uses this argument to prove that the use of mineral fertilizers is largely to neutralize toxic substances, but it could be used equally well to show that the synthesis of organic matter as well as the assimilation of minerals is an important factor in plant growth.

To show the value of organic matter in aqueous extracts of poor soils the Bureau of Soils, according to Cameron (5), used a manure extract as follows: One portion of the extract was evaporated and ignited to destroy the organic matter. The other part was used without ignition. The solution to which the unignited manure extract was added gave a far superior growth. Cameron attributes the value of the organic matter in the extract to its probable absorbent action on toxic substances, but it is also probable that the plants absorbed certain organic nutrients from it.

Gardner (11) determined the effect of many substances, mineral and organic, on transpiration and upon the amount of green matter

produced per unit of water transpired. The following figures give the summarized results of many trials:

Material added.	Growth due to fertilizer.	Growth per unit of water transpired.	Transpiration per unit of growth.
Nothing, check	100	100	100
P	104	103	97.0
K	113	107	93.6
KP	118	108	92.6
Lime	127	103	97.0
N	145	116	86.2
NP	144	119	84.0
NPK	152	123	81.3
NK	154	125	80.0
NPK lime	173	129	77.5
Manure	193	135	74.0
Clover and lime	197	143	69.9

It will be noted that the last two treatments, which are organic, not only gave the greatest growth, but gave the greatest growth per unit of water transpired. This work was done with soil solutions so the effects of the organic matter can not be due to its action on the physical condition of the soil, nor to its solvent action upon minerals. It is fair to conclude that the presence of carbon in the soil solution decreases the transpiration necessary to produce a unit of dry matter, a strong indication that plants may assimilate carbon through their roots.

Quarrie (32) reports large increases in garden crops through the application of carbon dioxide to the soil through pipes. Bornemann (2) reports like results with spinach. Mitscherlich (24), on the other hand, obtained no increase from the application of water saturated with CO_2. The possibility of adding an excess of water or of gas renders the results inconclusive. We know that in ordinary practice CO_2 producing materials are seldom injurious.

De Saussure (6) compared the growth of plants in pure water with water containing one-fourth its volume of carbon dioxide and found that the carbonated water was injurious to growth in the early stages, but not so later in the life of the plant. At the conclusion of the experiment the plants grown in the carbonated water weighed 46.4 grams, while those growing in pure water weighed 45.5 grams.

Hellreigel and Wilfarth (13), Franke (9), Berthelot (1), and Schlössing and Laurent (37) all report the utilization of organic nitrogen by green plants. Schreiner and his associates (39) have isolated creatinine, an organic nitrogen compound, from soils and proved its beneficial action upon plant growth. Lefèvre (18) grew plants in an artificial soil made from sand and moss, supplied with amids and sterilized so that further oxidation of these compounds would be

avoided. The entire plant was enclosed in an atmosphere freed from carbon dioxide. Under such conditions it is evident that any growth must result from the assimilation of the amids. Lefèvre obtained normal growth and concludes that: 1. In a soil supplied with amids one may develop green plants without carbon dioxide. 2. The growth thus produced is a real synthesis, not a *pousée aqueuse* (19). 3. Without light, synthesis from amids is impossible (20).

So much for nitrogenous organic substances. Molliard (25), using glucose, and Laurent (17) and Knudson (16), using other carbohydrates, have shown that plants assimilate sugars and that these sugars are used to synthesize dry matter.

Ravin (33) compared the effects of organic acids with their acid and neutral salts and concluded that such organic acids as malic, tartaric, citric, succinic, and oxalic may be assimilated by plants and further that these organic acids are more nutritive than their corresponding neutral salts or acid salts.

So far we have considered the assimilation of carbon from materials of known composition, namely, CO_2, amids, carbohydrates, and organic acids. Molliard (26), to put the matter on a more practical basis, experimented with humus extracted from soil. The work was carried on under sterile conditions, but it was impossible to prevent entirely the evolution of CO_2; therefore, definite conclusions can not be drawn.

The most conclusive proof that green plants can take up carbon compounds through their roots is their growth with the foliage enclosed in an atmosphere entirely devoid of carbon dioxide. Pollacii (30) grew plants in a culture bottle within a large receptacle, each being provided with tubes so that the water or air in each may be renewed and controlled independently of the other. The plants were sealed into the stopper with wax. By adding CO_2 to the nutrient solution and excluding it from the aerial portions of the plant he has successfully grown plants and even revived the chlorophyl in etiolated leaves.

From the evidence in the foregoing pages it may be concluded that green plants can, and probably do, take carbon through their roots. Just what form or what proportion of the total carbon in the plant this may be can not be stated, but the fact itself is enough to make us turn our attention to the soil organic matter.

DECOMPOSITION OF ORGANIC MATTER.

Hopkins (14) states that "It is the decay of organic matter and not the mere presence of it that gives life to the soil. Partially decayed peat produces no such effect upon the productive power of the soil as follows the use of farm manures or clover residues." Löhnis (23) declares that the organic matter is the life of the soil and upon its decay depends the fertility of the soil.

Realizing the importance of organic matter and its decomposition with reference to soil fertility, many investigations have been made to demonstrate the rate of decay and the factors influencing it.

Van Suchtelen (41) has used the rate of decay, measured by carbon-dioxide production, as a measure of bacterial activity. This method recognizes CO_2 as the ultimate and most representative end product of decay. He showed the influence of moisture and of frost, the effect of soluble sugars and of salts on bacterial activity. His results showing the action of fertilizers on the rate of decay are closely related to our subject and will be reported. He mixed the materials in 6 kg. of soil and determined the amount of carbon dioxide produced in 12 hours. His results were as follows:

Materials used	CO_2 produced.
6 kg. soil, no addition	145 mg.
6 kg. soil + 90 gr. $MgSO_4H_2O$	408 mg.
6 kg. soil + 6 gr. CaO	62 mg.
6 kg. soil + 30 gr. $(NH_4)_2SO_4$	864 mg.
6 kg. soil + 6 gr. superphosphate	306 mg.

The increases from applied materials are quite large with the exception of lime, which has evidently absorbed the gas produced. One function of fertilizers may be to hasten the decay of organic matter.

Lemmermann (21) and associates worked with the influence of lime compounds on decay. They compared the oxide and carbonate. They found that CO_2 production could not be taken as a measure of bacterial action with lime, because the oxide absorbed and the carbonate gave up CO_2. To offset the difficulty they carried on balance experiments in which the total carbon was determined before and after the incubation period, which lasted eight weeks. Their experiments show that (a) lime hastens decay, (b) kainit and a mixture of kainit and superphosphate do not increase decay, and (c) dry organic matter decays as rapidly as the same material fresh.

Potter and Snyder (31) report some work along this line. In their experiments the soil was placed in pots under bell jars and the CO_2 evolved was measured by drawing air over, not through, the soil. Their observations will be mentioned later.

Fred and Hart (10) showed that sulfate of ammonia, sulfate of potash, and phosphates increased the carbon-dioxide production, the first named to a marked degree.

Russell (36) measures oxidation by determining the oxygen absorbed rather than the CO_2 produced. Either method should give about the same results, for many analyses show that a high oxygen content of soil air is accompanied by a low CO_2 content and vice versa. In other words, the sum of the oxygen and carbon dioxide is nearly constant. Russell's method is to place the soil in a flask, connected on one side to a KOH flask and on the other side to a mercury tube. The KOH absorbs any CO_2 evolved and the rise of mercury in the other arm indicates the oxygen absorbed. He determined the oxidation of many soils by this method and concluded that in different soils of the same type the rate of oxidation varies in the same way as the fertility and may be used as a measure of it. This, if true, is important, for we have no other laboratory method of determining the relative fertility of soils.

Experimental.

The work of previous investigators indicates oxidation to be a measure of fertility in soils; hence, the rate of oxidation of organic additions should be a measure of their effectiveness. For the purpose of comparing organic materials ordinarily added to the soil the following series of experiments were planned.

For determining the rate of oxidation quart milk bottles were used. They were fitted with 2-holed rubber stoppers, one hole carrying a short glass tube while the other carried a tube reaching to the bottom of the bottle. Both tubes were fitted with short rubber connections stopped with glass plugs. Two hundred grams of washed gravel were placed in the bottom of the bottle to facilitate aeration and afford a space for the excess CO_2. The organic substance used in the test was thoroughly mixed with 300 grams of moist soil (25 per cent water) and placed on top of the gravel. The soil was moderately compacted by tamping.

The soil used was a fine, sandy loam of alluvial formation which had been under cultivation for many years. It was stored in covered ash barrels and not allowed to dry out, so the original bacterial flora was sufficient for the work. To make sure of this one bottle was inoculated with 10 c.c. of a manure suspension. This bottle gave the same amount of CO_2 as the uninoculated one after the first week of incubation, showing that there was no deficiency of organisms.

The rate of oxidation was determined by measuring the amount of CO_2 produced each week, as follows. The rubber connections were closed with pinch cocks, the glass plugs removed and the bottles connected with the absorption bottles as shown in figure 41. First is an absorption bottle (A) containing NaOH to free the incoming air of CO_2. Next is the incubation bottle (B) with its outlet tube reaching the bottom to make sure of complete removal of the CO_2 produced. The absorption apparatus (C) was devised to take the place of a Reisset (35) absorption tower. The tower (D) is an ordinary 100 c.c. pipette filled with broken glass or beads to increase the absorption surface. The pipette is connected with a Chapman filter pump. It was found that a rapid stream of air could be drawn through this tower without danger of incomplete absorption, and also that four minutes of strong aspiration was sufficient to remove all CO_2 from the generating flask.

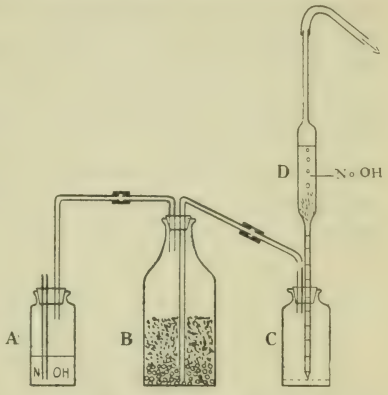

FIG. 41. Apparatus used in the experiments. See description in text.

Each bottle was aspirated once a week, using 50 c.c. of N/2NaOH as the absorbent. The CO_2 was determined by the double titration method (3). A 10 c.c. aliquot of the carbonated soda is titrated with phenolphthalein against HCl, first using normal acid until near the neutral point. Neutralization is completed with N/10 acid. This marks the conversion of carbonate to bicarbonate, neutral to phenolphthalein.

$$Na_2CO_3 + HCl + \text{phenolphthalein} \rightarrow NaHCO_3 + NaCl.$$

The amount of acid needed to make this change need not be known, nor is it necessary to know the normality of the alkali used.

Methyl orange is now added and N/10HCl run in drop by drop till the neutral point is reached. The exact amount is recorded and is equivalent to the CO_2 contained.

$$NaHCO_3 + HCl + \text{methyl orange} \rightarrow NaCl + H_2O + CO_2.$$

One cubic centimeter of N/10HCl equals 4.4 milligrams of CO_2.

Cochineal gives about the same results as methyl orange, but the latter was used throughout this work.

EXPERIMENT I, LEGUME FODDERS.

Soybeans, alfalfa, and red clover were used in this experiment. The plants were cut off at the surface of the ground when in full bloom or as near that stage as possible. They were dried, slowly at first and later in the oven. When dry they were ground and reground until all the material would pass through a 2-mm. sieve. Fifteen grams were mixed with 300 grams of moist loam, placed in the incubation bottles on top of a layer of gravel and slightly compacted. The bottles were stoppered and the outlet tubes closed with glass plugs. They were allowed to incubate in the dark at room temperature, the CO_2 produced being measured weekly (usually) in the manner just described. An untreated soil served as a check for all the following experiments. The results are shown in Table 1.

TABLE 1.—*Milligrams of CO_2 given off from untreated soil and from soil to which various legume fodders were added.*

Date.	Loam 300 gr. untreated.	Loam 300 gr. + soybean fodder 15 gr.	Loam 300 gr. + alfalfa fodder 15 gr.	Loam 300 gr. +red clover fodder 15 gr.
Nov. 15	35.2	475.2	444.4	426.8
Nov. 22	33.0	385.0	336.6	325.6
Nov. 29	50.0	211.0	242.0	154.4
Dec. 6	52.0	213.4	281.6	195.8
Dec. 13	37.4	167.4	200.2	182.6
Dec. 21	48.4	206.8	228.8	206.8
Dec. 28	50.6	237.6	193.6	162.8
Jan. 10	41.8	191.4	189.2	132.0
Jan. 17	37.4	195.8	167.2	143.0
Jan. 28	28.6	167.2	158.4	162.0
Feb. 6	35.2	160.6	165.0	169.4
Totals	449.6	2611.4	2607.0	2261.2

The results shown in Table 1 are plotted in figure 42. They show that a rapid production of CO_2 takes place the first two weeks after a legume fodder starts to decay, and that after the second week they settle down to a steady rate of decomposition. Apparently red clover decays a little slower than the other fodders, but there is no great difference between them.

There are possibilities of errors in the aspiration of the gas, but the irregularities in the curves are not due to these. Temperature changes affect all alike, hence the general tendency is for all to rise and fall at the same period, though not always in the same degree. The uniformity of the check indicates the accuracy of the method. Duplicates were run in the early part of the experiment but the close agreement seemed to justify dropping them to save work.

Humus Production.—Equally important as the rate of oxidation is the humus produced. A substance may oxidize very rapidly, as, for example, sugars, and still not increase the humus content noticeably. Such substances would be of questionable value as regards the physical improvement of the soil. Unpublished work by the writer shows that sugars break up very rapidly in the soil and are nearly com-

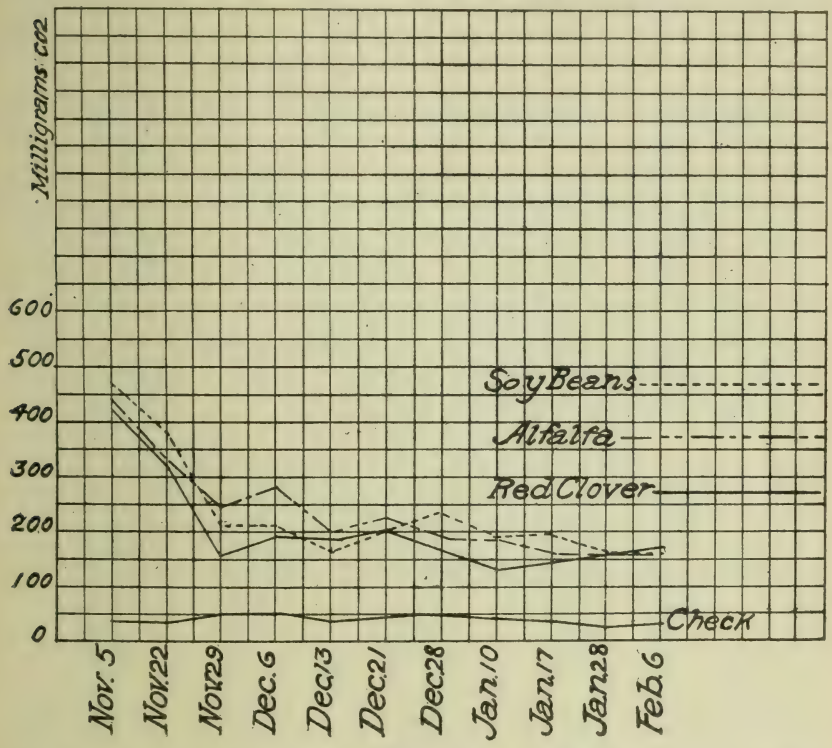

FIG. 42. Graph showing CO_2 given off during various periods from untreated soil and from soil to which various legumes were added. (Data from Table 1.)

pletely oxidized within a week or two. Lactose, maltose, saccharose, dextrose, and fructose run about the same. Sugar beets (figure 43) in the early stages of decay show the effect of their sugar, but later gave about the same results as rape and swedes.

The materials used in the CO_2 production experiments, having been allowed to incubate from November 8 to February 19, were removed, dried, and their humus content determined by the official method. The results are recorded below, together with the total CO_2 production for comparison.

Treatment.	Humus, percent.	Total CO_2, cg.
Soil, no treatment	2.96	44
Soil + alfalfa	3.43	260
Soil + red clover	3.29	220
Soil + soybeans	3.28	261

The figures indicate that there is little choice between the legumes in decay and humification.

EXPERIMENT 2, ROOT CROPS AND RAPE.

Root crops and rape were used to compare readily decomposable carbohydrates, as found in plants, with more inert materials. For this purpose sugar-beet roots, swede or rutabaga roots, and rape tops were used. All of these contain some form of stored food, sugar or starch. The plants were taken from the field, air dried, then oven dried, and ground fine enough to pass a 2-mm. sieve. Fifteen grams of each were mixed with 200 grams of moist soil and placed in incubation bottles as previously described. Determinations of CO_2 produced were made weekly. The results are shown in Table 2 and are also shown graphically in figure 43.

TABLE 2.—*Milligrams of CO_2 given off from untreated soil and from soil to which sugar beets, rutabagas, and rape were added.*

Date.	Loam 300 gr. untreated.	Loam 300 gr. + sugar beets 15 gr.	Loam 300 gr. + rutabagas 15 gr.	Loam 300 gr. + rape 15 gr.
Nov. 15	35.2	550.0	464.2	400.4
Nov. 22	33.0	708.4	484.0	396.0
Nov. 29	50.0	213.4	261.8	231.0
Dec. 6	52.0	235.8	226.6	244.2
Dec. 13	37.4	171.6	162.8	165.0
Dec. 21	48.4	132.0	189.2	206.8
Dec. 28	50.6	160.0	165.0	182.6
Jan. 10	41.8	125.4	147.4	158.4
Jan. 17	37.4	103.4	132.0	110.0
Jan. 28	28.6	118.8	114.4	149.6
Feb. 6	35.2	106.8	140.8	156.2
Totals	449.6	2625.6	2488.2	2400.2

Sugar beets, as might be expected, show rapid decay at the start but the sugar is all oxidized in two weeks, after which time the organic matter in them is no more decomposable than that of other materials. Rutabagas contain but little sugar and decay no faster than legume fodders. Rape is slowest at first but as time goes on it exceeds the others.

Comparing the legumes with roots we find that the former are

more readily oxidized as time goes on, that is, after the sugar in the roots is broken down.

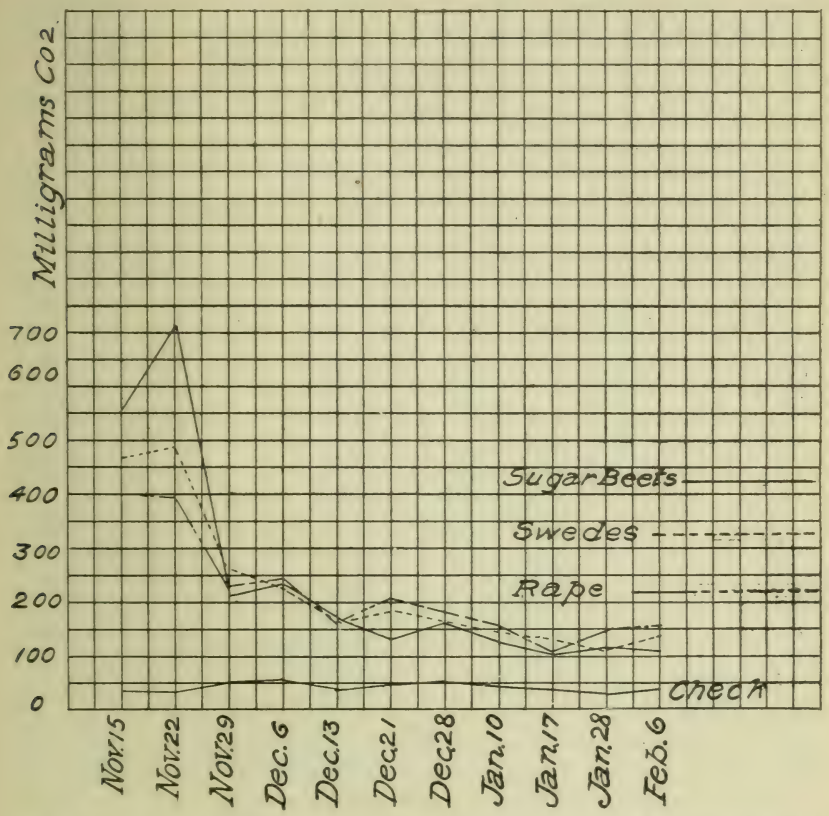

FIG. 43. Graph showing CO_2 given off during various periods from untreated soil and from soil to which sugar beets, rutabagas and rape were added. (Data from Table 2.)

The results of the humus determinations are as follows:

Treatment.	Humus, percent.	Total CO_2, cg.
Soil, no treatment	2.96	44
Soil + swedes	3.56	248
Soil + sugar beets	3.28	262
Soil + rape	3.24	240

The difference as shown by the humus figures seems the more representative, since the higher CO_2 production for sugar beets is due to the sugar. Rape falls in third place in both instances.

EXPERIMENT 3, LITTERS.

The materials listed below find their way into the soil through natural agencies or as litters and were selected with the expectation of obtaining large differences. It was thought that pine needles might even lower the bacterial activity, at least for a time.

Pine needles, oak leaves, and maple leaves were picked while still

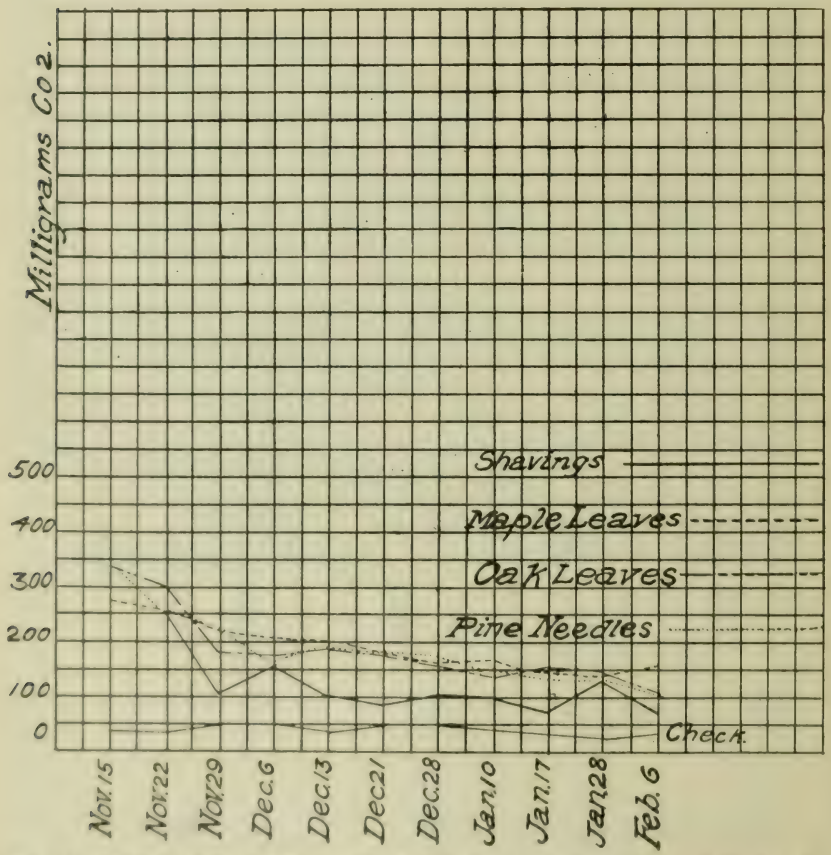

FIG. 44. Graph showing CO_2 given off during weekly periods by untreated soil and soil to which various litters were added. (Data from Table 3.)

green, air dried and later oven dried. White pine shavings, as used for litter, were oven dried. Each substance was ground and sieved. Fifteen grams were used in each case. The CO_2 determinations are shown in Table 3 and graphically in figure 44.

White pine shavings stand out as a striking example of an inert substance, being lowest and slowest in CO_2 production. Maple leaves give a more uniform decline than anything else.

The litters in general, as might be expected, are not as rapidly decomposed as either legumes or root crops and suggest the importance of nitrogen as an aid to oxidation, as those materials which are low in nitrogen are slow to oxidize. This latter statement applies to the later stages of decomposition.

TABLE 3.—*Milligrams of CO_2 given off from untreated soil and from soil to which various litters were added.*

Date.	Loam 300 gr. untreated.	Loam 300 gr. + shavings 15 gr.	Loam 300 gr. + maple leaves 15 gr.	Loam 300 gr. + oak leaves 15 gr.	Loam 300 gr. + pine needles 15 gr.
Nov. 15.....	35.2	257.4	275.6	338.8	343.2
Nov. 22.....	33.0	257.4	250.8	303.6	259.6
Nov. 29.....	50.0	118.8	224.4	182.6	224.4
Dec. 6.....	52.0	156.2	211.2	178.2	167.2
Dec. 13.....	37.4	103.4	206.8	187.0	193.1
Dec. 21.....	48.4	88.0	184.8	180.4	184.8
Dec. 28.....	50.4	105.6	167.2	162.8	178.2
Jan. 10.....	41.8	101.2	171.6	147.4	151.8
Jan. 17.....	37.4	77.0	149.6	158.4	136.4
Jan. 28.....	28.6	132.0	143.0	149.6	134.2
Feb. 6.....	35.2	74.8	160.6	116.6	110.0
Totals	449.6	1471.8	2145.0	2105.4	2083.4

The rate of oxidation, as measured by humus production and CO_2 production, follow the same order, namely, (1) maple leaves, (2) oak leaves, (3) pine needles, and (4) pine shavings. It should be noted that the shavings after having been in the soil for three or four months did not increase the percentage of humus; in fact, they lowered it slightly. The data are shown below.

Material used.	Humus, percent.	Total CO_2, cg.
Soil alone	2.96	44
Soil + maple leaves	3.34	214
Soil + oak leaves	3.18	210
Soil + pine needles	3.07	208
Soil + shavings	2.91	147

EXPERIMENT 4, CEREALS AND BUCKWHEAT.

Barley, oats, and buckwheat were used in this experiment because good samples of them were available. Barley and buckwheat are quite frequently plowed under as green-manure crops, which is not true of oats. Plants that were half matured were dried, ground, and mixed with the moist loam. The rate of oxidation is shown in Table 4. The data are also shown graphically in figure 45. Little or no consistent variation occurs. Buckwheat appears to be the most inert.

TABLE 4.—*Milligrams of CO_2 given off from untreated soil and from soil to which oats, barley, and buckwheat were added.*

Date.	Loam 300 gr., untreated.	Loam 300 gr. + oats 15 gr.	Loam 300 gr. + buckwheat 15 gr.	Loam 300 gr. + barley 15 gr.
Nov. 15	35.2	349.8	442.2	428.8
Nov. 22	33.0	338.8	283.8	380.6
Nov. 29	50.0	242.0	176.0	341.0
Dec. 6	52.0	239.8	182.6	281.6
Dec. 13	37.4	176.0	184.8	191.4
Dec. 21	48.4	253.0	138.6	195.8
Dec. 28	50.6	184.8	125.4	176.0
Jan. 10	41.8	189.2	162.8	138.6
Jan. 17	37.4	176.0	160.6	134.2
Jan. 28	28.6	184.8	158.4	118.8
Feb. 6	35.2	147.4	136.4	123.0
Totals	449.6	2481.6	2151.6	2539.2

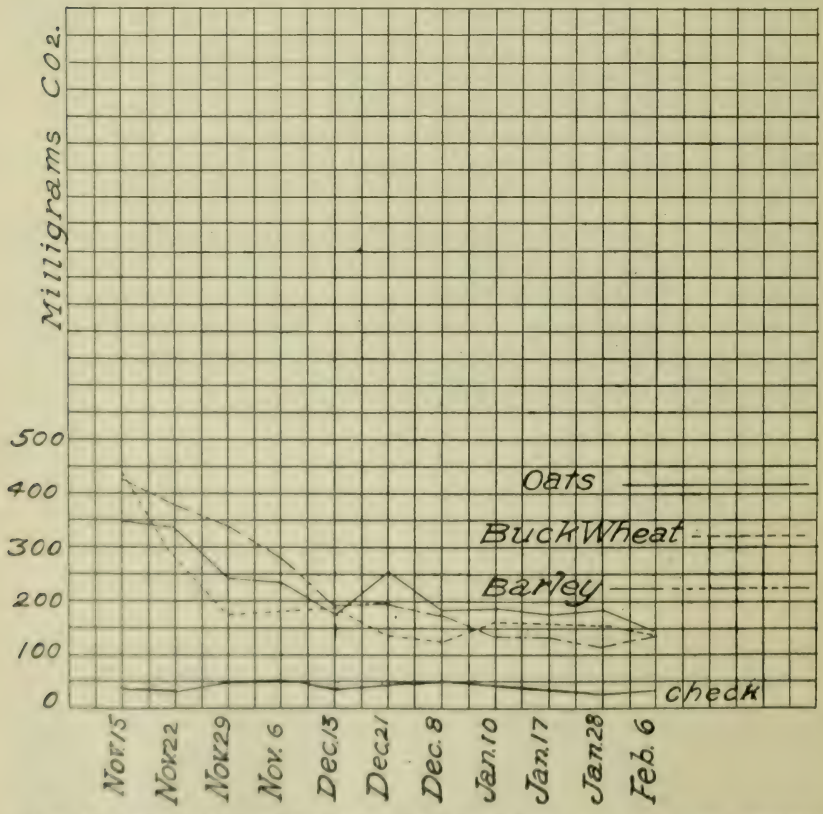

FIG. 4.—Graph showing CO_2 given off during weekly periods from untreated soil and from soil to which oats, barley, and buckwheat were added. (Data from Table 4.)

The data on humus production of oats, barley, and buckwheat are as follows:

Material.	Humus, percent.	Total CO_2, cg.
Soil alone	2.96	44
Soil + oat fodder	3.18	248
Soil + barley fodder	3.10	252
Soil + buckwheat fodder	2.99	208

The humus production of oats and barley is very nearly the same, the variation being within the limits of error. Buckwheat seems to be a very inert substance, increasing the percentage of humus almost nil, while the total CO_2 given off in three months is considerably lower than than the other materials.

GENERAL OBSERVATIONS.

Before the experiment was started it was expected that a wide variation in the rate of decomposition would be shown. Wollney (44) states that "Legume straws containing a high nitrogen content

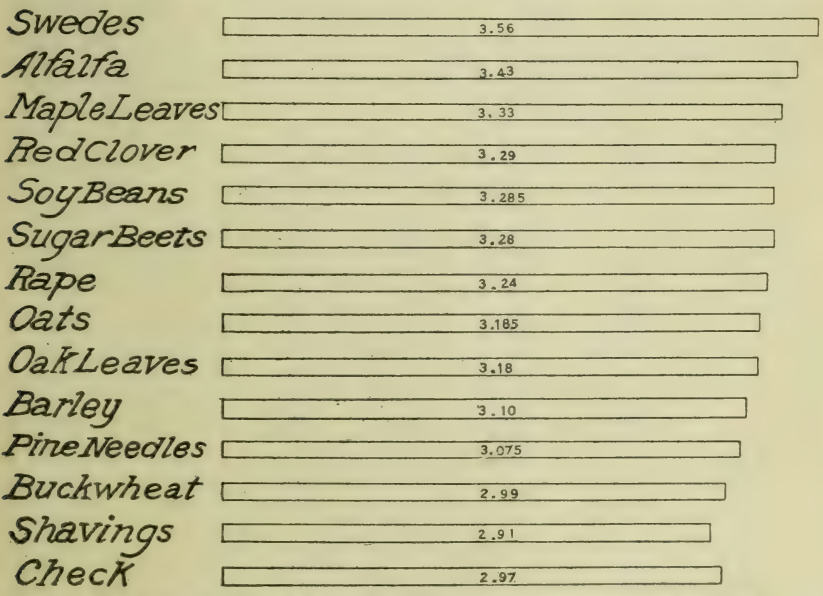

FIG. 46. Graph showing humus production from all materials used in the experiments.

are easily decomposed, grain straws are more resistant, while leaves and needles are still more so." The results show this to be true, but the difference is not as marked as might be expected. That white pine shavings should increase the CO_2 production as much as they did

is peculiar so it seems that the increased aeration afforded by the loose material has had some effect in causing a greater recovery of CO_2.

It should be remembered that all substances were dried before using, which may account for the uniformity of the results, although Lemmermann (21) found no difference between green and dry lucern. It would be nearly impossible to obtain, at the same time, all of the materials at the proper stage of growth and normal moisture content. To place everything on the same basis it seemed advisable to dry each in the same degree.

For the sake of comparison the humus production of all the materials is given in figure 46. It is believed that these results fairly represent the availability of the substances used.

Action of Fertilizers on Decomposition.

A second series of experiments was run along the same period as those just cited in an effort to determine whether or not fertilizer materials increased the rate of decomposition. The same form of apparatus was used. Fifteen grams of soybean fodder and one gram of the fertilizer to be tried out were added to each flask. The results are shown in Table 5.

Table 5.—*Milligrams of CO_2 given off by soybean fodder to which various fertilizing materials had been added.*

Date.	Soybeans alone.	Soybeans + sulfate of ammonia.	Soybeans + nitrate of soda.	Soybeans + ammonium phosphate.	Soybeans + calcium cyanamid.	Soybeans + acid phosphate.
Nov. 15	475.2	437.8	431.2	289.4	244.2	411.2
Nov. 22	385.0	365.2	545.6	374.0	330.0	374.0
Nov. 29	211.2	220.0	279.4	136.4	195.8	195.8
Dec. 6	213.4	228.8	297.0	198.0	206.8	209.0
Dec. 13	169.4	158.4	211.2	180.4	321.0	180.4
Dec. 28	237.6	187.0	235.4	224.4	182.6	195.8
Jan. 17	195.8	138.6	158.4	173.8	283.8	171.6
Jan. 28	117.2	145.2	143.0	154.0	162.8	132.0
Totals	2054.8	1881.0	2301.2	1830.4	1927.0	1870.0

Date.	Soybeans + raw bone;	Soybeans + basic slag.	Soybeans + sulfate of potash	Soybeans + kainit.	Soybeans + muriate of potash.
Nov. 15	296.0	413.6	446.6	352.0	407.0
Nov. 22	341.0	389.4	409.2	255.2	191.4
Nov. 29	228.8	193.6	209.2	224.4	204.6
Dec. 6	209.0	283.8	184.0	202.4	204.6
Dec. 13	169.4	259.0	191.4	158.4	136.4
Dec. 28	220.0	242.1	217.8	228.8	171.6
Jan. 17	167.2	187.0	147.4	167.2	134.2
Jan. 28	156.2	173.8	154.0	112.2	112.2
Totals	1887.4	2141.4	1952.8	1700.6	1562.0

The results show that but two of the fertilizer materials tried out increase the rate of decay; these are nitrate of soda and basic slag. The others show but little effect with the exception of kainit and muriate of potash, which decrease the rate quite markedly. The results with kainit agree with the carbon balance experiments of Lemmermann, previously mentioned.

Calcium cyanamid contains carbon, so it is not fair to draw any conclusions regarding its effect on organic decay as measured by CO_2 production. However, it appears to be toxic to soil bacteria as is shown by the markedly lowered production during the first two weeks. This toxic action seems to last but one week, agreeing with the recommendations of Brooks, Schneidewand, and others that the material be applied a week or two before planting time.

More experimental work of this kind has been done with sulfate of ammonia than any other fertilizer and contradictory results have been obtained. Van Suchtelen, using a light application of sulfate of ammonia and measuring the CO_2 for a very short period (12 hours), obtained much more gas from the treated soil. Fred and Hart (10) made determinations at 2-day periods and, while an increase over the check is shown, it is not nearly as great as the above. Potter and Snyder (31) found a slight decrease in CO_2 production from the use of sulfate of ammonia, as did the writer. The results of the last two experiments are not entirely contradictory to the former, for the time factor enters. It seems that the immediate effect of the salt is to increase or stimulate bacterial action, but it is not lasting. The results obtained here, as well as those of Potter and Snyder, represent a length of time equivalent to a growing season and for that reason should be of more practical value.

The residues from the oxidation experiments were dried and their humus content determined. The results were as follows:

Treatment.	Percentage of humus.
Soybeans 15 gr. alone	3.285
Soybeans 15 gr. + kainit, 1 gr.	3.225
Soybeans 15 gr. + raw ground bone, 1 gr.	3.195
Soybeans 15 gr. + muriate of potash, 1 gr.	3.180
Soybeans 15 gr. + sulfate of ammonia, 1 gr.	3.175
Soybeans 15 gr. + acid phosphate, 1 gr.	3.155
Soybeans 15 gr. + calcium cyanamid, 1 gr.	3.130
Soybeans 15 gr. + sulfate of potash, 1 gr.	3.035
Soybeans 15 gr. + ammonium phosphate, 1 gr.	3.000
Soybeans 15 gr. + rock phosphate, 1 gr.	2.990
Soybeans 15 gr. + basic slag, 1 gr.	2.970
Soybeans 15 gr. + nitrate of soda, 1 gr.	2.865

Those materials which markedly depressed the production of CO_2, viz., kainit and muriate of potash, caused the least loss in humus. This is shown by the relatively high humus content in the jars treated with those substances. On the other hand the materials which increased the production of CO_2, viz., slag and nitrate of soda, have markedly lowered the humus content. Considering this one may infer that fertilizers act upon the soil humus and not upon the crude organic matter. One would expect the continued use of materials like nitrate of soda to cause a rapid depletion of the soil's humus content.

Summary and Conclusions.

1. The legumes which are high in nitrogen show a more rapid rate of decay than straws and litters which are low in nitrogen. Nitrogen, then, seems to influence decomposition.

2. On farms where animal manures are not available the choice of green manures and cover crops is important. The results indicate that legumes would be most desirable on such farms.

3. Cyanamid appears to be toxic to soil bacteria, or at least arrests the decay of organic matter for two weeks after application.

4. Commercial fertilizers apparently act upon soil humus, decomposing it quite rapidly. They apparently do not act upon crude organic matter in the same way.

Literature Cited.

Editor's Note.—The citations of literature as originally made by the author in the preparation of his thesis were not as complete as those usually printed in The Journal of the American Society of Agronomy, and unfortunately he is not now able to complete some of them. It is hoped that they will be sufficiently complete to be useful to the reader.

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CROSS-POLLINATION OF SUGAR CANE.[1]

H. B. Cowgill.

Sugar cane has been propagated from seed and the seedlings selected for the purpose of originating new varieties since 1887. This was begun in Java and in Barbadoes at about the same time, and it has since been taken up in nearly all the cane-producing countries of the world. Originally no record was made of the parentage of the seedlings, and in many cases not even the name of the seed parent was kept. Some very good varieties were originated by this method.

For commercial purposes cane is propagated asexually by cuttings. When it is propagated from seed the variation in the resulting generation, even from a single parent variety, is considerable. It is presumed that some, if not all, of the varieties are more or less heterozygous. It seems nevertheless desirable, in many cases, to make controlled crosses in order to combine such characters as vigor and disease resistance of certain varieties with good qualities of other varieties.

[1] Contribution from the Porto Rico Insular Experiment Station. Received for publication July 23, 1918.

Methods of Crossing.

It would, of course, be desirable to eliminate all possibility of self-pollination. Attempts to emasculate the florets have been made, and a few seedlings have been produced in Barbadoes in that way; though, according to Bovell, the number of seedlings produced in any single season has been small. The work is very tedious, for the reason that the florets are small and the panicle is brittle. The latter is also produced at 10 to 15 feet from the ground, so that it is necessary to do the hybridizing on a scaffold and sometimes the wind makes the work very difficult.

Kobus (4),[2] in Java, planted a pollen-sterile variety on the leeward side of a pollen-fertile variety which flowered at the same time. Seeds of the former, when planted, grew and developed into canes which had characteristics of both parent varieties.

Another method reported by Bovell (1) to be employed in Barbadoes is to plant two varieties which flower at the same time in alternate stools, called the "checkerboard system," for the purpose of facilitating natural cross-pollination. It is of course impossible to form any conclusion as to the extent to which crossing takes place with this method, unless the type of seedlings produced by each variety when growing separately is known.

Two additional methods are described by Wilbrink and Ledeboer (6). By the first method the tassels of the variety to be used as the male parent are cut off and tied in position with the one to be used as a seed parent. For protection against undesired pollen a screen is provided, having an opening on the leeward side for the entrance of the tassels. By the second method the pollen of the desired variety is collected and carried to the one to be used as the female parent. This later method is also one which was suggested by D'Albuquerque (3). It is reported that the pollen adheres in masses, and also soon deteriorates, so that no very satisfactory results were obtained.

Methods Employed at the Insular Experiment Station.

Crossing has been practiced at the Insular Experiment Station of Porto Rico for four years. The method here described was found to be more suitable, for the reason that with its use a fairly large number of seedlings can be produced. The work has not yet progressed far enough to report results of the crossing, in respect to the quality of varieties produced. It has been possible, however, to study to some extent the populations of seedlings originating from different

[2] Figures in parentheses refer to "Literature cited," p. 306.

parentages, as to inheritance of characters in first-generation seedlings.

Bags made of cheese-cloth are held extended by heavy wire rings sewed into them. The bags when completed are 48 inches long and 18 inches in diameter. The rings are placed one at the top and the other 16 inches from the bottom, so that a skirt of 16 inches is left to be drawn in and tied around the stems of the panicles.

The bags are supported over the panicles by means of bamboo poles set in the ground. The poles have a crossbar at the top which is fastened to them by being wedged into notches cut into the second internode from the top, and the bags are tied to this crossbar. The poles are set on the windward side of the stools just before the panicles "shoot;" when this occurs, a bag is immediately suspended over each panicle and tied around its stem, so that it is protected from all undesired pollen before any of the florets open.

The cane blossom is hermaphrodite, but it has been found that certain varieties are almost completely pollen-sterile, or at least self-sterile. This makes it possible to pollinate them with another variety, with the assurance that nearly all the seedlings will be offspring of two known parent varieties, a few usually also being produced as the result of the self-pollination of the mother parent.

The pollinating is done by placing panicles of the desired variety into the bag, in such a position that their pollen will be shed or carried by the wind to the florets of the other variety as they open. One or two panicles are used at a time, and they are allowed to remain in the bag two or three days, being renewed as often as necessary while the florets are opening. It has been found of advantage to cut the panicles with stems 4 to 6 feet long, and to place their lower ends in a joint of bamboo filled with water, by which they can be kept fresh two or three days.

Results Accomplished.

Up to the present time, results can only be expressed in terms of the number of seedlings produced and the extent to which the characters of the varieties are combined. The method above described was first tried in 1915–16. Ten crosses were attempted, of a single combination, and all but two produced seedlings, a majority of which, when mature, showed characteristics of both parents. In all, about 1,000 seedlings were produced, one panicle alone giving over 1,000 seedlings (2).

In the following winter of 1916–1917, thirty crosses, comprising nine different combinations, were attempted, and nineteen of them,

comprising six combinations, were successful. From one combination 1,309 seedlings were obtained, and in all 2,589 seedlings were produced. The work was all done by one man and a helper, including the making of the bags.

In 1917–1918 it was impossible to secure the services of a competent man to perform the crossing until late in the season, and the seed of all varieties was also much less viable than in the preceding year. Thirty crosses were attempted, comprising nine combinations. Fifteen of these were successful and 1,794 seedlings were produced, 857 of which were from one combination and 735 from another.

Judging from the small proportion of the seedlings out of the large number propagated by the old method that are of sufficient value to become widely cultivated, it appears that a large number of first-generation seedlings is essential. Considered from the point of view of Mendelian inheritance, if many factors are involved, which is probably the case, the chance of getting a desired combination of characters is very remote when only a few seedlings are grown.

Effect of the Crossing.

In 1915–1916 the variety used as a pollinator was a dark-colored cane, while the seed parent was medium light. This made it possible to trace the color of the male parent in the offspring. Some other characters could also be traced in the seedlings in the same way. In the following year this cross was again made, and the same general effects were observed, many of the same types being again recognized (2).

In the year 1916–1917, some of the parent varieties of groups of seedlings showed fewer differences than was the case with the varieties combined the year before, consequently it was less easy to see the effect of the crossing in the seedlings. In all cases but one, however, some of the groups showed distinguishing characteristics of both parent varieties.

The disadvantage in this method, in not being able to eliminate all possibility of self-pollination, ought not to be overlooked. On account of the chance of some selfing, it has been the practice to estimate the value of a cross from the entire group of seedlings produced, always making allowance for probable self-pollination.

Self-Sterility.

At least two of the old standard varieties are nearly pollen-sterile here. We have never succeeded in producing more than one to five

seedlings from single flats of several hundred seeds planted, while if these same varieties are pollinated by any of several seedling varieties good germination follows. Lewton-Brain (5) in Barbadoes examined the florets of about fifty varieties and found that some bore pollen nearly all of which was large, well-shaped and full of dark granules, while with some the pollen was smaller, more or less irregular in form, and without granular matter. A third class of varieties had an intermediate amount of normal, well-developed pollen.

Wilbrink and Ledeboer (6) describe a method of testing the pollen with iodine, to determine its viabilty. If the pollen grain contains starch it was believed to be normal. We have not, however, found this test to be absolutely reliable.

Conclusions.

From the work reviewed in the foregoing paper the following conclusions are possible:

1. Sugar cane can be cross-pollinated and protected from outside pollen, and by this process a considerable number of seedlings can be produced.

2. Characters of the parent varieties are combined in the seedling by this process.[3]

[3] It should be expected that the desirable combinations could be perpetuated in hybrid condition because of the asexual method of propagation, a rather unusual advantage among our field crop plants. (Editorial note by L. H. Smith.)

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AGRONOMIC AFFAIRS.

ANNUAL MEETING IN BALTIMORE.

The eleventh annual meeting of the American Society of Agronomy will be held in Baltimore, Md., November 11 and 12. The call for papers for the program has been sent out by the Secretary. All who expect to present material at this meeting are urged to send titles at once to Lyman Carrier, Department of Agriculture, Washington, D. C.

ERROR IN THE JANUARY NUMBER.

The editor's attention has been called to an error which occurred in the article by Dr. George F. Freeman in the January issue of the JOURNAL. In Table 2, page 25, the words "hard" and "soft" are transposed throughout, so that the data are made to show just the opposite tendency from that actually indicated. All readers are requested to change the column headings in this table as here indicated.

MEMBERSHIP CHANGES.

The membership reported in the September issue of the JOURNAL was 652. Since that time 9 new members have been added and 10 have resigned, making the present membership 651. Names and addresses of new members, names of members resigned, and changes of address which have been reported follow.

NEW MEMBERS.

BIRCHARD, J. F., Cor. Magnus Ave. and Main St., Winnipeg, Manitoba.
BLACKWELL, C. P., Clemson College, S. C.
DAMON, S. C., Agr. Expt. Sta., Kingston, R. I.
ELLIOTT, B. S. A., School of Agr., Olds, Alta., Canada.
FERGUS, E. N., Agr. Expt. Sta., La Fayette, Ind.
GRISDALE, F. S., School of Agr., Vermilion, Alta., Canada.
MONTEAGUDA, HERIBERTO, Quinta de los Molinos, Habana, Cuba.
STEPHEN, W. J., School of Agr., Claresholm, Alta., Canada.
VAN SCHAIK, K. L., Pretoria, Transvaal, South Africa.

MEMBERS RESIGNED.

DAVISSON, B. S.,
DEETER, E. B.,
GRAY, WM. F.,
HITCHCOCK, E. B.,
LYNESS, W. E.,
NORTHROP, ROBT. S.,
SHERBAKOFF, C. D.,
SLEETH, E. C.,
YOUNG, HORACE J.,
ZAHNLEY, J. W.

Changes of Address.

Alexander, L. L., State Normal School, Springfield, Mo.
Bauer, F. C., 218 N. Lake St., Madison, Wis.
Beavers, J. C., Guilford College, N. C.
Bugby, M. O., Kingsville, Ohio.
Farrell, F. D., Agr. Expt. Sta., Manhattan, Kans.
Frear, D. W., Crop Estimates, U. S. Dept. Agr., Washington, D. C.
Freeman, Geo. F., Societe Sultanienne d'Agriculture, Cairo, Egypt.
Gernert, W. B., Farm Bureau, Paris, Ill.
Goddard, L. H., Washington Ave., Washington C. H., Ohio.
Jensen, L. N., Box 308, Big Springs, Tex.
Lund, Viggo, Tystoftu Expt. Sta., Tjaereby, Denmark.
Menzies, E. C., Aylesburg, Sask., Canada.
Miner, Sterling L., 1029 Sixth St., Greeley, Colo.
Petry, E. J., 210 South Ingalls St., Ann Arbor, Mich.
Southwick, Benj. G., Mass. Agr. College, Amherst, Mass.
Stadler, L. J., 410 South Maple St., St. Louis, Mo.
Thatcher, Lloyd E., Ohio Agr. Expt. Sta., Wooster, Ohio.
Tillman, B. W., Univ. of Mo., Columbia, Mo.
Walster, H. L., Soils Bldg., College of Agriculture, Madison, Wis.

ROLL OF HONOR.

The Society's roll of honor of men in military service now contains the names of 47 men. No doubt there are many others whose names have not been reported to the officers of the Society. The editor will appreciate information regarding men in the service of their country, both items of news and lists of names of men from various institutions who are now engaged in war activities. The names of those who have been reported to the editor follow.

Albert, A. R.,
Andrews, Myron E.,
Bliss, S. W.,
Brockson, W. I.,
Bruce, O. C.,
Brunson, A. M.,
Burnett, Grover,
Cates, Henry R.,
Chapman, James E.,
Childs, R. R.,
Deatrick, E. P.,
de Werff, H. A.,
Dickenson, R. W.,
Downs, E. E.,
Ellison, A. D.,
Freeman, Ray,
Gentle, G. E.,
Gilbert, M. B.,
Graham, E. E.,
Gray, Samuel D.,
Hanson, Lewis P.,
Holland, B. B.,
Hudelson, R. R.,
Jensen, O. F.,
Kenworthy, Chester,
Kime, P. H.,
Macfarlane, Wallace,
Moomaw, Leroy,
Newton, Robert,
Palmer, H. Wayne,
Piemeisel, R. L.,
Purington, James A.,
Quigley, J. V.,
Ratcliffe, Geo. T.,
Raymond, L. C.,
Richards, Phil E.,
Schneiderhan, F. J.,
Schoonover, W. R.,
Scott, Herschel,
Smith, J. B.,
Spencer, E. L.,
Stanley, C. W.,
Starr, S. H.,
Tabor, Paul,
Towle, R. S.,
Ware, J. O.,
Westbrook, E. C.

NOTES AND NEWS.

E. C. Chilcott, C. S. Scofield, and T. H. Kearney of the Department of Agriculture are now in Algeria, Tunis, and Morocco, where they are investigating the possibilities of increasing the agricultural output of these French colonies. The trip is being made at the request of the French high commission to the United States.

G. I. Christie, director of extension in Indiana and for the past several months assistant to the secretary of agriculture, has been named as assistant secretary, succeeding R. A. Pearson, resigned to resume his duties as president of Iowa State College.

G. H. Collings has been appointed assistant professor of agronomy and assistant agronomist at the Clemson (S. C.) college and station.

George F. Freeman, plant breeder of the Arizona station, has resigned to take up cotton-breeding and cultural work for the Egyptian Government in the valley of the Nile.

Ben C. Helmick, formerly assistant professor of agronomy in the Minnesota college of agriculture, is now instructor in agronomy in the Connecticut college and associate agronomist of the Storrs station.

C. G. Hopkins has been granted a year's leave of absence from the Illinois college and station to head the agricultural section of the Red Cross commission to Greece. He will study soil conditions, particularly with a view to the quick and permanent increase in food production. He will be assisted by George Bouyoucos of the Michigan station, the son of a Greek farmer, who has had fifteen years training and experience in this country.

W. L. Hutchinson, for the past several years professor of agronomy at Clemson College, has resigned and has been succeeded by C. P. Blackwell, who will also be agronomist of the South Carolina station.

J. S. Jones, formerly director and chemist of the Idaho station, has resigned to take charge of the operating laboratory of one of the Government's nitrate plants under the ordnance division of the War Department.

F. M. Rast, jr., formerly assistant professor of soils and fertilizers in the University of Florida, has been appointed assistant professor of agronomy in the Delaware college, succeeding M. L. Nichols, who is now in charge of extension work in farm engineering in Virginia.

Benjamin G. Southwick, formerly of the Connecticut college, is now demonstrator in farm management in the Massachusetts college.

J. L. Staden and C. C. Hearne have been appointed assistants in farm crops in the University of Missouri.

L. E. Thatcher has resigned as instructor in farm crops in Ohio State University and is now assistant agronomist in charge of plant-breeding work at the Ohio station.

B. W. Tillman, formerly of the soil survey force of the Federal Department of Agriculture, has resigned to become extension assistant professor of soils in Missouri.

H. L. Walster, who has been pursuing graduate study in plant physiology and ecology at the University of Chicago, has returned to his work at the University of Wisconsin, having received the Ph.D. degree at the August convocation. He will devote most of his time in Wisconsin to plant nutrition studies.

A committee to obtain information on food production conditions in Great Britain, France, and Italy, with a view to making these conditions known to agricultural leaders and to farmers generally in this country and to enable us to render aid more effectively to these countries, arrived in England September 1. The committee consists of Dr. W. O. Thompson, president of Ohio State University, chairman; Carl Vrooman, assistant secretary of agriculture; R. A. Pearson, president of Iowa State College; T. F. Hunt, director of the California station; D. R. Coker, farmer and member of the national agricultural advisory committee; W. A. Taylor, chief of the Bureau of Plant Industry; G. M. Rommel, of the Bureau of Animal Industry; and George R. Argo and John F. Wilmeth, of the Bureau of Markets.

Probably for the first time in history, the Federal Government has been making direct loans to farmers to finance fall seeding of wheat and rye. These loans are being made in Montana, North Dakota, Kansas, Oklahoma, and Texas, where crop failures during the past two years have been general over wide areas. Only those who can obtain funds in no other way are being financed. The work is under the joint supervision of the Treasury and Agricultural departments, the applications being approved by the Department of Agriculture and the loans completed by the Treasury Department, through the Federal land banks in these districts. G. I. Christie, assistant to the secretary of agriculture, has been in charge of the work in the northern district and L. M. Estabrook, chief of the bureau of crop estimates, has supervised the making of loans in the southwest. C. W. Warburton and H. N. Vinall have been chief assistants to Messrs. Christie and Estabrook, respectively. The loans are being made from the President's war emergency fund, $5,000,000 having been set aside for that purpose. The portion of the fund not loaned this fall will be used for financing seeding of spring wheat.

Third Western Agronomic Conference.

Agronomic workers in the eleven western states met in the third western agronomic conference at Corvallis, Oreg., July 23, 24, and 25, 1918. The meetings were attended by more than forty agronomic workers representing the various State experiment stations, agricultural colleges, and extension departments, the United States Department of Agriculture, and the British Columbia Department of Agriculture.

Roland McKee of the Office of Forage Crop Investigations, U. S. Department of Agriculture, stationed at Chico, Cal., discussed experimental methods for establishing forage standards. He emphasized the importance of basing forage yields on the oven-dry basis because of varying rates of loss of moisture after cutting with different varieties, and also with light and heavy yields of the same variety. H. A. Schoth of the same office, stationed at Corvallis, Oreg., discussed production problems in connection with forage-crop experiments.

Experimental work in the prevention of smut explosions and in grain cleaning in the smut-infested areas of the Northwest, as well as means of collecting smut spores to prevent soil infection, was presented by C. C. Ruth, of the Portland grain supervision office, Bureau of Markets. H. P. Barss, professor of botany and plant pathology of the Oregon college, discussed the smut and rust control work under way in the United States and the splendid results accomplished by the pooling of interests of the plant pathologists throughout the country.

R. L. Stewart of the New Mexico college presented a very interesting paper on the utilization of soaproot and sotol as forage for range cattle. He stated that thousands of head of cattle had been carried through the period of forage shortage by feeding these plants finely chopped. Range management in Wyoming was discussed by A. F. Vass, agronomist of the Wyoming station. He showed the direct relation between dry years and loss of stock and also the relation between prices and the rise and decline of the stock population of the State.

O. E. Barbee of the Washington station presented a season's data on the influence of date of seeding on winter wheat. Row versus plat plantings for varietal tests of cereals were discussed by D. E. Stephens, superintendent of the Moro, Oreg., substation. Reliable results have been obtained at this station from row tests.

J. A. Clark, agronomist in charge of western wheat investigations for the U. S. Department of Agriculture, presented the scheme of classification of wheat varieties worked out by C. R. Ball and himself, and then illustrated the scheme by taking the visiting agronomists to the wheat nursery of the Oregon station, where the various commercial varieties of wheat of the United States were being grown.

Soil problems in the Palouse district, particularly with reference to humus and nitrogen, were discussed by F. J. Sievers of the Washington college. Experimental work with alkali soils in Utah was presented by B. W. Pittman, and soil survey problems in Oregon and Idaho were discussed by C. V. Ruzek and E. B. Hitchcock, respectively. The follow-up work after the mapping and physical classification were completed was stated to be of maximum importance.

W. L. Powers of the Oregon college presented a paper on some phases of experimental work in farm management, and George Stewart of the Utah college talked of irrigation investigations being conducted in that State. The results of an extensive survey of problems of the field-pea growers of Idaho were presented by H. W. Hulbert.

A round-table discussion on the bulk handling of grain in the Pacific Northwest was led by A. L. Rush of the Bureau of Markets and G. R. Hyslop of the Oregon college and was participated in by many of those present. The discussion of factors affecting quality of wheat was introduced by J. W. Gilmore of the University of California. It was agreed by those present that quality of wheat was dependent on both soil and climatic conditions.

H. D. Scudder, professor of farm management in the Oregon college, presented plans for land colonization in Oregon, particularly with reference to a model farm colonization unit.

Farm crops work offered in the various western colleges was presented in tabular form and discussed by E. G. Schafer of the Washington college, particularly with regard to its relation to other required work. Agronomic extension work was discussed by Leonard Hegnauer and R. J. Leth, extension specialists in agronomy in Washington and Idaho, respectively. The importance of extension correspondence was particularly emphasized.

The invitation of Professor Gilmore to hold the 1919 conference in Berkeley was accepted, and the date of the meeting was set for early June. Professor Gilmore was elected chairman of the 1919 conference, and named Roland McKee and G. R. Hyslop as additional members of the committee on arrangements. As some of the agronomic meetings in the Middle West have now been abandoned, it is hoped that agronomists from that section will join with western agronomists in the 1919 conference at Berkeley.

G. R. Hyslop, *Secretary.*

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INFLUENCE OF HIGHER PLANTS ON BACTERIAL ACTIVITIES IN SOILS.[1]

T. LYTTLETON LYON.

In considering the relation of plants to soils attention has in general been more concerned with the effect of the soil on the plant than with the influence which the plant may exert on the soil. When, however, the latter has received consideration it has been mainly from the standpoint of the quantity of fertility removed. In more recent years investigations have been conducted to ascertain the effects of green-manuring crops or of systems of crop rotations on nitrogen transformations in soils.

The subject to which I wish to call your attention is the immediate influence of the growing plant on certain bacterial processes in the soil, a subject which has a bearing on the practical problems of crop production and which is now in that interesting stage of suggestion that is so alluring to the investigator.

The literature of soil investigation is not rich in indications that the bacterial flora and its activities are influenced by growing plants, but some such suggestions may be found, and they give a reasonable basis for encouraging further investigations. I shall not attempt an exhaustive review of this literature, but shall mention some of the work that appears most significant. I find only a few investigations that attempt any correlation between the growing plant and the bacterial flora. One is a piece of work by Hoffmann in which he counted the number of bacteria in soil immediately adjacent to plant roots and

[1] Presidential address before the eleventh annual meeting of the American Society of Agronomy, January 6, 1919. Read by C. E. Leighty in the absence of President Lyon.

at some distance away. He examined a large number of plants of different genera and species and found almost uniformly a denser flora near the roots. He is also supported by Stoklasa, who found under different crops marked differences in the germ content of the soil. It will, of course, require a very considerable number of tests to establish the certainty that roots of growing plants improve the surrounding soil for the development of bacteria and that certain higher plants are more effective than others in this respect. It is mentioned here, however, because the possibility is suggested rather strongly.

A class of microorganisms whose activities, there is reason to believe, are influenced by growing crops is that portion of the flora which reduces nitrates to less highly oxidized forms of nitrogen. An unaccountable disappearance of nitrates from soils on which crops were growing has been noted by several investigators. A number of explanations have been proposed. Dehérain attributes it to the drying out of the soil by the growing plants during the season most favorable for nitrification. Warington thought that it might be due to denitrification with loss of nitrogen into the air and possibly to loss of nitrogen from the plant. Russell merely states that it indicates a diminished production of nitrates and Leather is inclined to accept the explanation which will be given later.

A typical example of this disappearance of nitrates may be found in the lysimeter experiments of Dehérain in France, Leather in India, and of the Cornell experiment station. In all of these experiments certain plants grown in lysimeters from which both the plants and drainage water were analyzed gave as a balance at the end of the experiment less nitrogen in the crop plus the drainage water of the planted soil than in the drainage water alone of the soil on which no plants grew. No analyses having been made of the soil it is uncertain what finally became of the nitrogen that failed to appear either in the crop or in the drainage water.

It is evident that the problem must be attacked in a different way and to do this plants were grown in nutrient solutions which were kept sterile through the entire period of the growth of the plants, amounting in some cases to nearly a year. In these solutions contained in 12-liter flasks plants were grown to maturity and maize reached a height of 6 feet. The solution being sterile when the plant was harvested, it could be used as a medium in which to conduct bacterial transformations of nitrogen with pure cultures. To study the possible disappearance of nitrate nitrogen the solution in which the plant had grown had added to it a definite quantity of a nitrate salt

and, after inoculation with a nitrate-reducing organism, it was incubated and the quantity of nitrate that disappeared in a certain time was ascertained by analysis. This was compared with a similar nutrient solution in which no plant had grown. Without taking the time that would be consumed in presenting the figures involved in this and other experimental work described in this paper I may say that there appeared to be a markedly more rapid reduction of nitrates in the solution in which the plant had grown than in the other, the experiment being repeated many times.

The composition of the nutrient solution in which the plant had grown and the one in which it had not was, of course, different on account of the removal of certain substances by the plant. To make the two as nearly similar as possible 10 c.c. of the solution in which the plant had grown was added to 90 c.c. of another medium. The same was done with the solution in which no plant had grown and under these conditions the solution in which the plant grew increased the rate of nitrate reduction more than did the solution in which no plant grew. Analyses of the solutions after incubation showed that part of the nitrates had been converted into organic forms.

Infusions of macerated plant roots were made and reduction of nitrates tested in solutions to which these were added. It was found that such infusions increased nitrate reduction and that the more infusion added the more rapid was the disappearance of nitrate. Mannite was used in the incubated solutions as a source of energy for the bacteria and it was found that within certain limits an increase in the quantity of mannite served to hasten nitrate formation. The organic matter available to the reducing organisms is doubtless a factor in determining their activity.

In solutions in which plants grew as well as in media to which infusion of macerated roots was added it was attempted to ascertain whether nitrate reduction went on in the presence of an antiseptic, phenol being used. Such reduction did occur while it did not do so in check solutions, but it was slight and the evidence indicates that the effect of growing plants on nitrate reduction is due only in part to enzymotic action. Reducing enzymes were generally found, however, in plant solutions and in root infusions. Oxidates were sometimes shown to be present in plants growing in agar, timothy roots always giving reaction for these. Reactions for peroxidases were always obtained in agar near the roots of all plants tested. Boiling the solutions before inoculation lessened nitrate reduction, thus indicating that enzymes or some similar substances played a part in the process.

The experiments that have been described indicate two possible ways in which higher plants may influence bacterial activities in soils. One of these is through the result of plant growth on the composition of the soil solution. Experiments by a number of investigators show that the relative quantities of certain anions and cations in solution may influence the rate of the nitrifying process. The presence or absence of organic matter has also been shown to be a factor.

The experiments that have been mentioned indicate that both of these conditions may influence reduction of nitrates. The growing plant may be expected to have an influence on the composition of the soil solution. From the time that the plant begins to grow until it reaches the stage of full bloom it is absorbing nutrients from the soil solution with slight if any return to the soil. During this period there is doubtless a decrease in the concentration of the soil solution, as absorption apparently proceeds faster than solution. After the stage of full bloom a marked diminution in the absorption of the solutes begins. A change in the composition of the soil solution may be looked for during the later stages of growth of the plant. It is during the middle and later stages of growth that the reduction of nitrates appears to be most marked. Plants of different kinds also differ in respect to the quantities and rates of nutrients absorbed and may thus be expected to exert different effects on the rate of reduction of nitrates.

Another possibility is that the organic matter in the soil solution is more or less influenced by plant growth and that this organic matter affects the activities of the bacteria that bring about the transformations of nitrogen. The organic matter in solution constitutes a very small part of the total organic matter of the soil. Being in solution it is in a condition to affect bacterial activity. In the experiments previously mentioned there was found in the solutions in which plants had grown a half percent as much organic nitrogen as was found in the plant at maturity, altho these solutions were originally composed only of inorganic substances. This organic matter given off by the plant roots may conceivably be a factor in the depressing effect on the nitrate content of soils.

In trying to determine the action of any plant on transformations of nitrogen little can be learned by making incubation tests of the soil placed in flasks. The aeration and partial drying which the soil undergoes in the process is likely to nullify any effect which the crop may have had. It is well known that either complete or partial drying

of a soil results in materially increasing its solubility. Any effect that the plant may have exerted on the composition of the soil solution would therefore be changed and nitrogen transformations may be very different from what they would have been in the untouched soil. Even the operation of plowing causes a change in the rate of nitrate formation, as has been shown by Brown and MacIntire. The best way to determine the ultimate effect of a crop on nitrate formation is to remove the crop and allow the soil to incubate without disturbing it, at the same time maintaining an optimum moisture content.

Another bacterial process in soils which appears to be influenced by some higher plants is the production of carbon dioxide. Under certain conditions the carbon-dioxide content of the air of soil on which plants had matured was lower than that of soil on which no plants had grown, altho the opposite was the case during the time the plants were making their greatest growth. Both nitrate production and carbon-dioxide formation are associated with the decomposition of organic matter and it would thus appear that this process is in a measure at least controlled by crop growth.

Not only does there appear to be a depression of nitrate production by certain higher plants, but other of these plants seem to have a stimulating influence on the formation of nitrates. This, however, appears to be exerted only during the early stages of growth. There is not so much evidence regarding this property of plants as there is regarding their depressive action, but there is some indirect experimental indication of its occurrence.

Fraps found that 50 to 100 percent more nitrogen was removed from the soil by maize plants in the first nine weeks of their growth than was apparently transformed from organic compounds into ammonium and nitrate salts during the same time.

The figures given by Stewart and Greaves in a study of nitrates in irrigated soils planted to maize, potatoes, and alfalfa, and also on land fallowed during a period of three years and planted to oats one year, show nitrates to be higher under maize at certain stages in the growth of the crop than in fallow land. The same was true of potatoes in their later experiments.

Results reported by Jensen showed that soil planted to maize contained more nitrates during the first part of July than did fallow land.

Bower determined nitrates in soil of unplanted plots both cultivated and uncultivated, and in maize plots cultivated and uncultivated. In both cultivated and uncultivated plots nitrates under the maize were higher during July than in the bare soil.

Similar results have been obtained in our experiments in the field and also in lysimeters. In the lysimeter experiments records were kept of the quantity of nitrogen removed annually in the drainage waters and in the crops, the period for the calculations beginning May 1 and closing April 30 following. This covers the period during which the crop is on the soil and the interval before the next planting, during which time conditions are favorable for leaching out the nitrates that may have accumulated in the soil during the summer. Comparing the quantities of nitrogen thus removed in the drainage water of unplanted soil with the nitrogen in the crop plus that in the drainage water of planted soil we found that for maize the total quantity of nitrogen removed in the crop and drainage was considerably greater than from the unplanted soil. From oat soil slightly more nitrogen was removed than from bare soil, but from soil growing timothy and other true grasses less nitrogen was so removed.

Taken as a whole these experiments indicate that with maize there is a stimulating influence on nitrate formation which is more potent than the depressing influence, while with timothy the opposite is the case. Oats appear to be intermediate between maize and timothy in their influence on nitrate formation and it is doubtful whether the stimulating or depressing effect is greater.

Laboratory experiments in which methods were employed similar to those used to test the activities of nitrate-reducing bacteria were conducted with ammonifying bacteria. These gave some slight indication that the solutions in which plants had grown produced somewhat more ammonia from peptone than did similar solutions in which no plants had grown. Owing to the difficulty in getting pure cultures of nitrate-forming organisms the influence of plants on formation of nitrates has not been tried with these methods.

Decomposition of organic matter is commonly and doubtless properly regarded as one of the most important factors in rendering a soil fertile. If a crop can stimulate or retard this process at certain stages of its growth it holds the key that locks or unlocks the supply of plant nutrients for its own use and possibly influences to some extent the supply for the crops that follow. It has long been held that plants possess the power of rendering available for their own use the food materials contained in soils. The idea was advanced by Sachs that plant roots excrete organic acids which act on the inorganic matter of soils, dissolving a part of that which comes in immediate contact with the root hairs and thus rendering it suitable for absorption. That organic acids other than carbonic are excreted by plant roots was discredited by the investigations of Czapek and there are few scien-

tists who still believe that plants secure nutrients by such a process. The fact still remains that some plants apparently obtain more of certain inorganic substances from soils than would appear to be possible from their solubility in water. Certain other plants obtain much smaller quantities of these nutrients. The influence which these plants exert on the decomposition processes in the soil may be a factor in determining whether they obtain much or little nutriment.

Clover and alfalfa also appear to have a marked effect on bacterial activity in soils. It has, of course, been known from an early time that plants of this class increase the productivity of a soil both when plowed under and when raised for hay. The discovery some 30 years ago of the symbiotic relation of nitrogen-fixing bacteria and leguminous plants apparently explained in full the reason for their usefulness in promoting soil fertility. Since the growth of legumes on properly inoculated soil results in fixation of atmospheric nitrogen and therefore in an increase in the quantity of nitrogen in a soil the conclusion naturally follows that the resulting improvement in crop production is due to the increased supply of nitrogen that follows the growth of legumes.

If, however, it is found that the growth of a legume has not increased the nitrogen content of a soil and yet that the productivity of that soil has been augmented, how then are we to account for the effect of the legume? An examination of the data at hand calls for the formulation of a different explanation.

That the growth of a legume is not always accompanied by a greater accumulation of nitrogen in the soil than is the growth of certain native prairie grasses has been strikingly brought out by Swanson, who determined the nitrogen content of a large number of soils in the state of Kansas. Half of the samples were from alfalfa fields of from 20 to 30 years standing and the remainder had been in native grass pastures. In each case the alfalfa field and the pasture were near together and apparently of the same soil type. His results show that the alfalfa did not leave the soil any richer in nitrogen than did the other cropping treatment. Somewhat similar results were obtained by Alway and Bishop with soil from a clover field and a contiguous one in nonleguminous crops.

At the Cornell experiment station four adjoining plots of land, two of which had been in timothy for six years and two in alfalfa for the same length of time, were carefully sampled and the nitrogen content of the soil determined. There was no difference between the timothy and alfalfa soil on one section and only 0.01 percent on the other. When these were plowed and planted to maize the alfalfa soil pro-

duced about one-third larger crop of maize than the timothy soil. The legume had in this case increased the productivity of the soil as compared with timothy, but had accomplished this without leaving any larger nitrogen balance.

Determinations of nitrates in the soil of these plots when kept free of vegetation and also in samples of the soil incubated after the addition of dried blood showed a more rapid formation of nitrates in the alfalfa soil. There are two possible explanations for the greater nitrification in the alfalfa soil. Either the nitrogen left in the soil by the legume was more easily nitrifiable than the nitrogen in the timothy soil and likewise than that in dried blood or else the alfalfa plants had a stimulating effect on the activities of the nitrate-forming bacteria.

In this experiment the roots of the alfalfa plants showed the presence of tubercles and there was no reason to think that nitrogen fixation was not normal. Yields of the hay from these plots were estimated by weighing several, but not all, of the crops and these were analyzed for nitrogen. The figures show that there must have been a large fixation of atmospheric nitrogen by the alfalfa to supply this removal without depleting the store of soil nitrogen below that in the timothy soil. It seems probable that the more rapid formation of nitrates in the alfalfa soil, together with the well-known propensity of that plant to use nitrate nitrogen even when inoculated with nitrogen-fixing bacteria, drew on the supply of accumulated nitrogen to such an extent that the final balance was no greater than it was in the timothy soil.

I do not intend to question the well-known fact that the nitrogen content of a soil may sometimes be augmented by the growth of legumes even when the above-ground portions of the plants are removed, but I think it is fairly questionable whether the beneficial effect of legumes on soil productivity is due entirely to this increase in the nitrogen content or whether it is in part accomplished through some other influence which the plant exerts on the bacterial activities within the soil.

These observations suggest the desirability of further investigating the conditions which determine the rate of accumulation and loss of soil nitrogen attending the growth of legumes. It is well known that a liberal supply of basic material in soil encourages the growth of red clover and especially of alfalfa, but this condition of the soil also favors the formation of nitrates which are absorbed in varying degree by the clover or alfalfa plants and are likewise leached from the soil by the percolating rainfall. It is questionable, therefore, whether a well limed soil would in the end show a larger balance of nitrogen fol-

lowing the growth of a legume than would a soil which has barely enough basicity to successfully produce the crop.

Again the question arises as to the kind of legume best qualified to leave a large nitrogen balance in a soil. It is recognized that some legumes are capable of growing on more acid soils than are others. If the nitrogen-fixing power of all legumes were the same it is conceivable that the nitrogen balance resulting from their growth would be greater for those kinds that grow successfully on acid soil, because nitrate formation proceeds more slowly on such soils and the lesser use of nitrate nitrogen may compel a larger fixation of atmospheric nitrogen. From the point of view of nitrogen accumulation it may possibly be better for the farmer whose land is moderately sour to raise the legumes that are adapted to that soil rather than to lime it. In connection with this it now occurs to me that the Volusia silt loam of southern New York has a rather high content of organic nitrogen in spite of its slow rate of nitrate formation, while some of the more easily nitrifiable soil types contain less total nitrogen. However, we must admit that a large supply of nitrogen that is not available does not add to the value of a soil. It is possible that excessive basicity in a soil in a humid region is undesirable when considered from the standpoint of nitrogen economy.

The experiments to which I have referred in this paper and the speculations in which I have indulged suggest another interesting and it may be useful line of investigation, namely, the effect of one crop on another growing in association with it. Mixed seedings of certain small grains have been found by several experimenters to yield more than either grown alone. Apple trees have often been found to grow poorly in sod land. The latter difficulty I think is in some cases clearly due to the depressing effect of the grass on the formation of nitrates in the soil and the consequent lack of nitrogen in the nutrition of the trees.

Mixed seedings of a legume with a nonlegume often result in more vigorous growth of the nonlegume than when the latter is grown alone. Mixtures of the grasses with clover or alfalfa are likely to give especially good results, as the strongly depressing influence of the grass on nitrate formation is to some extent offset by the stimulating influence of the clover crop. There are doubtless a number of conditions that exercise an influence on the results of these mixed plantings and the nature and extent of these is a further subject of investigation. It seems possible that plants like maize which themselves have a stimulating influence on nitrate formation do not benefit from association with legumes as do plants that depress nitrification. Lime

applied to soils on which lime is needed apparently increases the benefit to the nonlegume as does also the application of suitable fertilizer.

The subject which I have outlined in a superficial way touches many aspects of crop production. Its study, however, is difficult. The complex nature of the soil and the rapid chemical and biological changes that occur when a soil sample is removed from the field or vessels in which plants are grown may entirely mask the effects produced by plants. New methods must be devised and great patience must be exercised in the investigation of this subject. It is nevertheless one of the problems that must be solved if we are to have the fundamental knowledge on which to base a rational system of crop management.

THE PREPARATION OF MANUSCRIPTS FOR PUBLICATION.

C. W. WARBURTON.

The preparation of manuscripts for publication in the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY or elsewhere deserves more than passing attention. If material is worth presenting at all, it is worth presenting in the best possible form. Carelessness or haste in the preparation of a paper often results in its rejection, even tho the matter it contains is otherwise worthy of publication. A poorly prepared paper, if published, is unsatisfactory to the writer and to the reader, unless the editor devotes much time to its revision.

Clearness and accuracy of expression are of major importance. Naturally, not all men have the same ability to present facts in clear, concise language, but all can strive to obtain clarity of expression. Fine writing should be avoided. A short word is far better than a long one if it conveys the same idea quite as effectively. If six words can be made to do the work of ten, the omission of the useless verbiage is a distinct gain. To quote George Otis Smith:[1] "The . . . scientist has at least two obligations: First, that of making his investigations more and more exact in method and direct in result; second, that of making his product, the written report, such as to meet the needs of not only his professional associates but also the general public."

It is not the intention, however, to make this brief note a discussion of style, but rather one of form. Articles concerned with instruc-

[1] Smith, George Otis. Plain writing. *In* Science, n. s., 42: 630–632. 1915.

tion, demonstration, experimentation, or research in agronomy will be accepted for publication in this journal. They may be reports of the results of original research, or they may be reviews of the work of others. Reviews of literature, however, should be critical digests of the available material on a subject rather than mere lists of titles. It is understood that articles submitted for publication have not been published previously elsewhere and that they will not be offered for simultaneous publication in other journals without the consent of the editor of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY. Papers varying in length from 1 to 32 pages are acceptable; short papers will in general be given preference.

Form of Manuscript. Articles for publication should be typewritten on sheets approximately 7 by 11 inches in size. Carbon copies are not acceptable, as they are often blurred and are frequent sources of error, particularly in tabular matter. A duplicate copy should be retained by the author. Text pages should be double or triple spaced, preferably the latter, with wide margins. If the body of the text is triple spaced, double spacing may be used for quotations, citations, etc. Single spacing allows no opportunity for editorial changes and should never be used. The principal sections of the article should be indicated by subheadings, the relative rank of the subheadings being shown by underscoring or other means. Every page of a manuscript, including tables, should be numbered consecutively.

Illustrations. Only such illustrations as are distinct additions to the text and aid in a clear understanding of it are acceptable. Each illustration must be specifically referred to in the text. Line drawings (text figures) are preferable to photographs, which require the making of half-tone engravings and printing on separate plates. Text figures should be numbered consecutively in the order of their occurrence, using Arabic numerals. Always refer to illustrations by number, as "figure 12," not "the following figure." If a distinct portion of a figure is referred to, it should be indicated by a capital letter in the text reference and also in the drawing itself, as "figure 14A." Text figures should be drawn in India ink on white or tracing paper, though the use of cross-section paper is permissible if it can not be avoided. All lettering should be clear and distinct. Each figure should be accompanied by a brief descriptive legend, plainly written.

Photographs, when essential for use as illustrations, will be reproduced as plates. Ordinarily two illustrations are reproduced on a single plate. Reference to plates should be by number, as "Plate 2, figure 1." Photographs for reproduction should be clear, black and white glossy prints. They should be unmounted, but should be

attached slightly at the corners to a sheet of paper of the same size as the text of the manuscript. This sheet should bear the plate and figure numbers and a short descriptive legend.

Tabular Matter. No other feature of editing occasions so much labor as the putting of tabular matter in form for publication. All table legends should be clear, concise, descriptive statements of the matter in the table. Tables should be numbered consecutively in Arabic numerals, and references to tables should always be by number, as "Table 4," not "the following table." Arrange the data in the most compact form which will present clearly the information desired. Each column heading should indicate the nature of the data in that column. The unit of measure should be expressed in the legend if all data in the table are in the same unit, as "Dry weight in grams of crops grown, etc." If more than one unit is used, the unit for each column should be specified at the top of that column.

Tables preferably should be written on separate sheets from the text matter. Care should be taken to limit the number of columns so that the table can be printed without difficulty on a page 4¼ inches wide. Otherwise, rearrangement and rewriting by the editor is usually necessary. If duplicate or replicate determinations were made, only the averages should in general be submitted for publication, though the duplicate determinations may be sent for the editors' inspection. Footnotes to tabular matter should be designated by letters rather than index figures.

Footnotes should be numbered consecutively throughout the paper, the first number being reserved for the date of receipt of the paper for publication and such other identifying statement as may be desirable. Copy for footnotes should be inserted in the text on the line immediately following the reference, and should be cut off by ruled lines above and below. If the text is triple spaced the footnotes may be double spaced.

Citations of Literature may be printed as footnotes, though if they are several in number they may better appear at the end of the paper under the heading of "Literature cited." Citations so appearing should be arranged in alphabetic order and should be numbered consecutively. Reference in the text should be by this number, enclosed in parentheses. If more than one paper by an author is cited, the references should be in the order of their publication, the earliest being cited first. Citations should include the name of the author, with initials, title of article, name of publication in which it appeared, with volume and page if a periodical, and date of publication. Write "*In*" before titles of periodicals. Book citations should show place

of publication and, preferably, name of publisher. Note the following examples, and also recent issues of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY.

11. GARDNER, FRANK D. Fertility of soils as affected by manures. U. S. Dept. Agr., Bur. Soils Bul. 48, p. 54. 1908.
8. BRIGGS, L. J., and SHANTZ, H. L. The wilting coefficient for different plants and its direct determination. U. S. Dept. Agr., Bur. Plant Indus. Bul. 230, 83 p., 9 fig., 2 pl. 1912.
1. ALWAY, F. J. Studies of soil moisture in the Great Plains region. *In* Jour. Agr. Sci., 4: 333–342. 1908.
3. ALWAY, F. J. Moisture studies of semiarid soils. *In* Rpt. 79th Meeting British Asso. Adv. Sci., p. 698, 699. 1908.
14. HOPKINS, C. G. Soil Fertility and Permanent Agriculture, p. 195. Ginn & Co., Boston. 1910.

Figures and Abbreviations. Use Arabic numerals to express percentages and measures of quantity or space, except at the beginning of a sentence, as "9 bushels," "15 miles." Abbreviate metric weights and measures in all cases, but English weights and measures only when enclosed in parentheses, as "15 cm.," "45 bushels," but (45 bu.). Use gm. for gram(s), cm. for centimeters(s), c. c. for cubic centimeter(s), kg. for kilogram(s). Use "percent," not "per cent," "per cent.," or "%."

Capitalization and Spelling. Follow Webster's New International Dictionary in capitalization and spelling. Spell "sulfur," "sulfate," and their compounds with "f." Capitalize important words in citations of book titles, but use small letters in citing titles of articles or bulletins.

Proofs. Only one proof will be furnished. This should be read carefully, the necessary corrections indicated on the margin, and returned promptly to the editor. Do not make corrections in the text without indicating them also in the margin. Changes in figures, particularly in tabular matter, should never be written over the originals. Make only absolutely necessary changes in the proofs. The original manuscript should be so written that radical changes in the proof are unnecessary. Proof, if unaccompanied by other matter, may be mailed at the rate of 1 cent for each 2 ounces.

Reprints. Fifty reprints of each paper without covers are furnished free to authors. Additional reprints will be supplied at cost. Covers are supplied at the rate of $1.00 for the first 50, and 1 cent each for additional copies. Orders for reprints should always accompany the proof when it is returned.

AGRONOMIC AFFAIRS.

DELAY IN PUBLICATION OF THE JOURNAL.

Because of the unavoidable postponement of the annual meeting of the Society, it has been necessary to delay publication of the December number of this journal in order to include the annual reports of the officers and committees and the minutes of the annual meeting. The January, 1919, number has already been mailed and the succeeding numbers of volume 11 will be sent out on time, so far as possible.

THE YEAR'S WORK.

As stated in the annual report of the editor, printed elsewhere in this issue, the publication of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY during 1918 has not been accomplished without difficulty. The editor has been absent from his office during the greater part of the year, and as a consequence some of the issues have been late in appearing. Not all have been up to the standard which it is desirable to maintain, while the exigencies of the times have made a reduction in the size of the annual volume necessary. The efforts of the members should now be devoted to the building up of the Society thru an increase in membership, thus making possible a larger and better publication in 1919.

HONOR ROLL.

As the entrance of several men into military service has been reported since the last previous issue of the JOURNAL was published, it is desirable to again print the Society's honor roll, so that the record may be as complete as possible. So far as known, 55 of the Society's members have been or are now in military service, tho the list may still be far from complete. Those whose names are known to the editor are as follows:

ALBERT, A. R.,
ANDREWS, MYRON E.,
BLISS, S. W.,
BROCKSON, W. I.,
BRUCE, O. C.,
BRUNSON, A. M.,
BURNETT, GROVER,
CATES, HENRY R.,
CHAPMAN, JAMES E.,
CHILDS, R. R.,
CURREY, HIRAM E.,
DEATRICK, E. P.,
DE WERFF, H. A.,
DICKENSON, R. W.,
DOUGLAS, J. P.,
DOWNS, E. E.,
ELLISON, A. D.,
FREEMAN, RAY,
GENTLE, G. E.,
GILBERT, M. B.,
GRAHAM, E. E.,
GRAY, SAMUEL D.,
HALVERSON, W. V.,
HANSON, LEWIS P.,

HEAD, A. F.,
HELM, C. A.,
HOLLAND, B. B.,
HUDELSON, R. R.,
JENSEN, O. F.,
KARLSTAD, C. H.,
KENWORTHY, CHESTER,
KEPHART, L. W.,
KIME, P. H.,
MACFARLANE, WALLACE,
MINER, STERLING,
MOOMAW, LEROY,
NEWTON, ROBERT,
PALMER, H. WAYNE,
PIEMEISEL, R. L.,
PURINGTON, JAMES A.,
QUIGLEY, J. V.,
RATLIFFE, GEO. T.,
RAYMOND, L. C.,
RICHARDS, PHIL E.,
SCHNEIDERHAN, F. J.,
SCHOONOVER, W. R.,
SCOTT, HERSCHEL,
SMITH, J. B.,
SPENCER, E. L.,
STANLEY, C. W.,
STARR, S. H.,
TABOR, PAUL,
TOWLE, R. S.,
WARE, J. O.,
WESTBROOK, E. C.

NOTES AND NEWS.

Roy O. Bridgeford has been elected instructor in agronomy at the Morris (Minn.) school of agriculture and F. W. McGinnis has been made instructor in farm crops in the same institution.

L. A. Clinton, for the past several years assistant chief of cooperative extension work north and west in the U. S. Department of Agriculture, on November 1 succeeded Alva M. Agee as director of extension in New Jersey. Mr. Agee will continue as State commissioner of agriculture.

Howard S. Coe, assistant agronomist in the office of forage-crop investigations, U. S. Department of Agriculture, died at Beaumont, Texas, October 25, 1918, of pneumonia following influenza. Mr. Coe was born at Orrville, Ohio, September 24, 1888. He graduated from Iowa State College in 1913 and was granted the degree of M.Sc. by the same institution in 1915. From September, 1913, to July, 1914, he was botanist and plant pathologist of the South Dakota station, resigning on the latter date to enter the service of the Department of Agriculture. His work during the past four years was for the most part in connection with studies of clover, sweet clover, velvet beans, and Southern pasture plants. He was the author of several bulletins of the Department of Agriculture and was a valued contributor to the pages of the JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY, of which Society he was a member. Mr. Coe was married in September, 1914, to Lela Marie Skinner, of Brookings, S. Dak., who, with a young son, survives him. He was an energetic worker of marked ability, and his loss is keenly felt by his associates.

F. D. Farrell, for the past several years in charge of demonstration work on reclamation projects for the Department of Agriculture, since September 1 has been dean and director of the Kansas college and station.

L. H. Goddard has resigned from the States Relations Service, U. S. Department of Agriculture, to devote his entire time to his

farming interests in Ohio. His work in connection with farm management demonstrations has been taken over by the Office of Farm Management and will be directed by L. H. Moorhouse.

Aven Nelson, for the past year acting president of the University of Wyoming, has been elected president.

Ralph W. Redman, formerly of the States Relations Service, U. S. Department of Agriculture, is now assistant director of extension in Massachusetts.

C. W. Stanley, after a year's service with the Canadian Expeditionary Forces, is now assistant analyst at the Ontario Agricultural College.

F. H. Steinmetz has been elected assistant professor of farm crops and assistant agronomist of the Minnesota college and station and August Haedecke has been made assistant in agronomy of the same station.

John H. Voorhees has been added to the extension staff in farm crops at Cornell University.

W. O. Whitcomb, for the past five years assistant professor of agronomy at the Montana State College, has resigned to take charge of the Minneapolis office of the Seed Reporting Service, U. S. Department of Agriculture.

Meeting of the New England Agronomists.

The New England agronomists held their annual meeting in Boston, November 16, 1918. Those in attedance were G. E. Simmons of Maine; M. Gale Eastman and F. W. Taylor of New Hampshire; A. B. Beaumont, H. P. Cooper, Earl Jones, and B. G. Southwick of Massachusetts; G. E. Adams of Rhode Island; and Henry Dorsey, B. C. Helmick, and W. L. Slate, jr., of Connecticut.

An informal meeting was held on the evening of November 15 at the Parker House. The seed potato question was discussed, and Professor Slate outlined his plan for inspection by the Food Administration of potatoes shipped into Connecticut. All those which do not meet the requirements for seed stock are sold for food. During the discussion, it was suggested that the New England stations try certified seed potatoes in comparison with common northern grown seed.

At the morning session on November 16 the potato score card was discussed. Professor Adams told of his experiments with certified seed and of his work with potatoes at the Rhode Island station. Professor Cooper of the Massachusetts station then talked on the grading and judging of corn. The question of how to pick out the best samples in a corn show was discussed, and it was suggested that other features might be added to corn shows, such as economical production, germination tests, milling quality, etc. Mr. Southwick of the Massachusetts college talked on the teaching of agronomy from the farm management standpoint.

A committee appointed to draft the sentiments of the New England agrono-

mists on the value of corn shows and methods of conducting them, consisting of Jones, Southwick, and Dorsey, reported as follows:

"In recognition of the fact that high-scoring corn as judged by our present scorecards may not necessarily be high-yielding corn, therefore, be it resolved that it is the sense of the New England agronomists that an attempt should be made to so modify our scorecards and other bases of comparison in judging corn that the factors of yield per acre and economical production may be given a larger recognition than at present, and that the chief object of corn shows should be to emphasize these two factors."

On the passage of this resolution, the president appointed a committee to work on the problems brought out by the discussion, assigning a problem to each member, as follows: (1) To work out a plan for experimental work with good and poor corn as judged by the scorecard, Professor Adams; (2) to work on the scorecard, Professor Cooper; and (3) to work on corn judging as related to boys' and girls' work, Mr. Eastman.

Professor Beaumont of the Massachusetts station discussed soil surveys for New England. Following the passing of a resolution urging the taking of an inventory of the soil fertility resources of New England and one authorizing the appointment of a committee of three to bring the question of soil surveys before the meeting of experiment station directors of the New England, New York, and New Jersey stations, the chair appointed a committee for this purpose consisting of Messrs. Beaumont, Simmons, and Slate.

Following a discussion of teaching after the war, a resolution urging the adoption of a four-term system instead of the semester system by New England colleges was passed, with the suggestion that if the change is made the work in crop production should be scheduled during the growing season. The secretary was instructed to send copies of this resolution to the presidents of each of the New England agricultural colleges. The secretary was also instructed to communicate with the New England Society for Rural Progress, with a view to the presentation of agronomic problems before that organization.

Professor Slate was reelected president and Professor Jones secretary and treasurer for the ensuing year.

REPORT OF THE SECRETARY-TREASURER.

The present Secretary-Treasurer received his appointment from the President, Dr. T. Lyttleton Lyon, under date of March 11, 1918, following the resignation of Mr. P. V. Cardon. This report covers the period from that date to December 31, 1918, and includes the subscriptions, dues, etc., collected by the previous Secretary-Treasurer, subsequent to the filing of his report on March 1, 1918.

The year 1918 has been the most disastrous period in the history of the Society. In previous reports there has always been recorded a substantial growth; this one shows a decided decrease in membership. This decrease is due to several causes, perhaps most of all to the uncertainty of the positions of many of the younger members, owing to the draft. This has been an obstacle also in getting the usual number of new members. It is only fair to state, however, that the list of delinquents in the payment of dues contains the names of a number of the older agronomists. Whether these lapses were due to carelessness or were intentional, the Secretary can not say. There were some 260 members in arrears March 1. Since then two requests for payment have been sent, making three for the year.

During the period covered by this report, 23 new members have been added to the Society, 2 have died, 5 have resigned, and 98 have been dropped for nonpayment of dues. The Honor Roll of those entering the military service contains 55 names. It is quite likely that some who have been dropped for nonpayment of dues belong on the Honor Roll. If so, the Secretary will gladly make due correction if his attention is called to the error.

The Society has a paid-up membership of 509, including 10 members on the Honor Roll to whom the JOURNAL has been sent. The names and addresses of these 509 members are printed elsewhere in this issue. Together with 45 others whose names are included in the Honor Roll on page 326, the Society's membership at this time is 554. In addition to this membership list, there are 90 subscriptions to the JOURNAL from libraries and other institutions.

FINANCIAL STATEMENT FROM MARCH 11, 1918, TO DECEMBER 31, 1918.

Receipts.

Received from P. V. Cardon, former Secretary			$1,083.60
Dues from members:			
165 members for 1918	at	$2.50	$412.50
1 member for 1918	at	2.00[a]	2.00
1 member for 1917–18	at	2.00	4.00
4 members for 1919	at	2.50	10.00
19 new members for 1918	at	2.50	47.50
1 new member for 1918	at	2.25[b]	2.25
1 new member for 1918	at	2.00[a]	2.00

[a] Fifty cents still due to the Society.
[b] Agent's commission deducted.

2 new members for 1919	at	2.50	5.00
2 student members for 1919	at	1.25	2.50
13 local members for 1918 (N. C. section)	at	.50	6.50
1 advance payment on 1919 dues			1.00
JOURNAL and *Proceedings:*			
11 subscriptions for 1918	at	2.50	27.50
5 subscriptions for 1918	at	2.25[b]	11.25
1 subscription for 1918	at	2.40[b]	2.40
12 subscriptions for 1919	at	2.25[b]	27.00
1 subscription for 1919	at	2.50	2.50
Sale of volumes previous to 1918			90.65
Sale of reprints			61.85
Interest on bank deposit			3.83
Total recipts			$1,805.83

Disbursements.

1918.			
March	25.	Postage	$ 10.00
April	1.	Maurice Joyce Eng. Co.	6.93
April	13.	Postage	10.00
April	15.	Maurice Joyce Eng. Co.	1.50
April	19.	Mary R. Burr, clerical help	8.50
May	18.	New Era Printing Co.	202.06
June	10.	New Era Printing Co.	234.97
June	14.	Mary E. Burr, clerical help	5.00
July	10.	New Era Printing Co.	311.96
July	22.	C. W. Warburton, postage, etc.	12.00
Aug.	1.	Postage	8.00
Aug.	1.	Mary R. Burr, clerical help	5.00
Aug.	30.	New Era Printing Co.	108.74
Aug.	30.	Maurice Joyce Eng. Co.	48.69
Sept.	4.	New Era Printing Co.	173.80
Sept.	5.	Postage	10.00
Oct.	3.	Maurice Joyce Eng. Co.	35.48
Oct.	8.	Postage	10.00
Oct.	8.	J. L. Wilson, postage, etc.	.65
Oct.	29.	Lewis M. Thayer, printing	5.75
Nov.	23.	Mary R. Burr, clerical help	17.80
Dec.	6.	Maurice Joyce Eng. Co.	4.50
Dec.	6.	Lewis M. Thayer, printing	4.50
Dec.	28.	Postage	5.00
		Total disbursements	$1,240.83
		Balance December 31, 1918	565.00
			$1,805.83

LYMAN CARRIER,
Secretary-Treasurer.

By vote of the Society the report of the Secretary-Treasurer was adopted.

The report of the Editor, as published elsewhere, was read and adopted.

The report of the Committee appointed to canvass the votes on the amendment to Article 4 of the Constitution of the American Society of Agronomy to read, "The officers of The American Society of Agronomy shall be a President, a First Vice-President, a Second Vice-President, and a Secretary-Treasurer." The committee, consisting of W. B. Ellett and A. B. Beaumont, reported 183 votes for the amendment, 1 against, and 3 defective. The constitution was declared so amended.

The nominating committee, consisting of C. A. Mooers and Robert Getty, reported the following nominations:

President, J. G. Lipman, New Jersey Agr. Expt. Sta.
First Vice-President, F. S. Harris, Utah Agr. Expt. Sta.
Second Vice-President, A. B. Conner, Texas Agr. Expt. Sta.
Secretary-Treasurer, Lyman Carrier, U. S. Dept. of Agriculture.

By vote of the Society, these nominees were duly elected officers for the year 1919.

The report of the Committee on Standardization of Field Experiments, prepared by the Chairman, A. T. Wiancko, was read and adopted.

On motion, it was voted that the Executive Committee consider the advisability of affiliating with the American Association for the Advancement of Science and if thought desirable to leave the matter to a mail vote of the whole Society.

Meeting adjourned.

Address List of Members.

Abell, M. F., College of Agriculture, Storrs, Conn.
Adams, G. E., Agr. Expt. Sta., Kingston, R. I.
Agee, John H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Aicher, L. C., Aberdeen Experiment Farm, Aberdeen, Idaho.
Albrecht, W. A., College of Agriculture, Columbia, Mo.
Alexander, L. L., State Normal School, Springfield, Mo.
Allen, Edward R., Agr. Expt. Sta., Wooster, Ohio.
Allyn, Orr M., Fergus, Mont.
Alvord, Emory D., Agr. Expt. Sta., Pullman, Wash.
Alway, F. J., University Farm, St. Paul, Minn.
Anderson, Arthur, University Farm, Lincoln, Nebr.
App, Frank, Rutgers College, New Brunswick, N. J.
Arny, A. C., University Farm, St. Paul, Minn.
Atkinson, Alfred, Agr. Expt. Sta., Bozeman, Mont.
Atwater, C. G., The Barrett Co., 17 Battery Place, New York, N. Y.
Ayrs, O. L., Tenn. Coal and Iron Co., Birmingham, Ala.
Babcock, F. R., County Agent, Crosby, N. Dak.
Bachtell, M. A., Ohio State University, Columbus, Ohio.
Bailey, C. H., University Farm, St. Paul, Minn.
Baker, O. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Ball, C. R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Bancroft, Ross L., Iowa State College, Ames, Iowa.
Barbee, O. E., Cliff House, Pullman, Wash.
Barre, H. W., Agr. Expt. Sta., Clemson College, S. C.

Bartlett, Harley H., 335 Packard St., Ann Arbor, Mich.
Bauer, F. C., 218 N. Lake St., Madison, Wis.
Bear, F. E., College of Agriculture, Columbus, Ohio.
Beaumont, A. B., College of Agriculture, Amherst, Mass.
Beavers, J. C., Guilford College, N. C.
Beeson, M. A., Oklahoma A. and M. College, Stillwater, Okla.
Bell, Henry G., 1111 Temple Bldg., Toronto, Canada.
Bennett, Chas. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Bennett, Hugh H., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Berry, Roger E., 404 Knoblock St., Stillwater, Okla.
Biggar, H. Howard, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Billings, G. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Birchard, J. F., Magnus Ave. and Main St., Winnipeg, Canada.
Bizzell, James A., Cornell University, Ithaca, N. Y.
Blackwell, C. P., Agr. Expt. Sta., Clemson College, S. C.
Blair, R. E., Yuma Experiment Farm, Bard, Calif.
Bledsoe, R. Page, Experiment Farm, Waterville, Wash.
Block, J. F., Dept. of Interior, Calgary, Alberta, Canada.
Bolley, H. L., Agr. Expt. Sta., Agricultural College, N. Dak.
Boss, Andrew, University Farm, St. Paul, Minn.
Boving, Paul, Univ. of British Columbia, Vancouver, B. C., Canada.
Bower, H. J., Kansas State Agr. College, Manhattan, Kans.
Boyack, Breeze, Agr. Expt. Sta., Fort Collins, Colo.
Bracken, John, Saskatchewan Univ., Saskatoon, Sask., Canada.
Brandon, Jos. F., Akron Field Station, Akron, Colo.
Breithaupt, L. R., R. F. D. No. 3, Payette, Idaho.
Brewer, Herbert C., The Barrett Co., 17 Battery Place, New York, N. Y.
Briggs, Glen, Experiment Farm, Agana, Guam.
Brodie, D. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Brown, B. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Brown, E. B., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Brown, P. E., Iowa State College, Ames, Iowa.
Bryant, Ray, Stillwater, Okla.
Buckman, H. O., Cornell University, Ithaca, N. Y.
Bugby, M. O., Kingsville, Ohio.
Bull, C. P., University Farm, St. Paul, Minn.
Burdick, R. T., 635 N. California St., Stockton, Calif.
Burgess, Jas. L., Dept. Agriculture, Raleigh, N. C.
Burgess, P. S., Hawaiian Sugar Planters Expt. Sta., Honolulu, Hawaii.
Burlison, W. L., Room 607 D. Agr. Bldg., Univ. of Ill., Urbana, Ill.
Burnett, L. C., Iowa State College, Ames, Iowa.
Burr, W. W., University Farm, Lincoln, Nebr.
Burtis, Earl, 325 E. Olive St., Fort Collins, Colo.
Bushey, A. L., Plankinton, S. Dak.
Butler, Ormond R., Agr. Expt. Sta., Durham, N. H.
Call, L. E., Agr. Expt. Sta., Manhattan, Kansas.
Calvino, Mario de, Estacion Expt. Agron., Santiago de las Vegas, Cuba.
Cardon, P. V., Judith Basin Expt. Farm, Moccasin, Mont.
Carleton, M. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.

Carr, Ralph H., 24 N. Salsbury St., La Fayette, Ind.
Carrier, Lyman, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Chambliss, Chas. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Champlin, Manley, Agr. Expt. Sta., Brookings, S. Dak.
Chappelear, Geo. W., Normal Station, Harrisonburg, Va.
Chilcott, E. F., Woodward Experiment Farm, Woodward, Okla.
Childs, R. R., College of Agriculture, Athens, Ga.
Churchill, O. O., Agricultural College, N. Dak.
Clark, Chas. F., Box 747, Greeley, Colo.
Clark, Chas. H., Bur. Plant Indus., Dept. Agr., Washington, D. C.
Clark, J. Allen, Bur. Plant Indus., Dept. Agr., Washington, D. C.
Clemmer, H. J., Woodward Experiment Farm, Woodward, Okla.
Clevenger, C. B., University of Wisconsin, Madison, Wis.
Cocke, R. P., Williamsburg, Va.
Coffey, G. N., Extension Dept., Univ. of Ill., Urbana, Ill.
Cole, John S., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Coleman, L. C., Director of Agr., Bangalore, Mysore, India.
Conn, H. J., Agr. Expt. Sta., Geneva, N. Y.
Conner, A. B., Agr. Expt. Sta., College Station, Texas.
Conner, S. D., Agr. Expt. Sta., La Fayette, Ind.
Conrey, G. W., College of Agriculture, Columbus, Ohio.
Cooper, H. P., Mass. Agr. College, Amherst, Mass.
Cooper, M. L., Merryville, La.
Cowgill, H. B., Box 333, Fort Smith, Ark.
Cowles, Henry C., University of Chicago, Chicago, Ill.
Cromer, C. Otis, Agr. Expt. Sta., La Fayette, Ind.
Cron, A. B., Box 1214, Amarillo, Texas.
Cunningham, C. C., Agr. Expt. Sta., Manhattan, Kans.
Curtis, H. P., County Agent, Sutton, W. Va.
Cutler, G. H., Univ. of Alberta, Edmonton South, Alta., Canada.
Daane, Adrian, 225 Duncan St., Stillwater, Okla.
Damon, S. C., Agr. Expt. Sta., Kingston, R. I.
Darst, W. H., Dept. Agr., State College, Penn.
Davidson, Jehiel, Bur. Chemistry, U. S. Dept. Agr., Washington, D. C.
Davis, R. O. E., Bureau of Soils, U. S. Dept. Agr., Washington, D. C.
Dean, H. K., Umatilla Experiment Farm, Hermiston, Ore.
Deatrick, Eugene P., Kutztown, Penn.
Delwiche, E. J., 1221 Chicago St., Green Bay, Wis.
Dillman, A. C., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
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Dorsey, Henry, College of Agriculture, Storrs, Conn.
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Yoder, P. A., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Young, Philip H., Agr. Expt. Sta., Manhattan, Kans.
Youngblood, Bonney, Agr. Expt. Sta., College Station, Texas.
Zavitz, C. A., Ontario Agr. College, Guelph, Ont., Canada.
Zinn, Jacob, Agr. Expt. Sta., Orono, Maine.
Zook, L. L., North Platte Substation, North Platte, Nebr.

Lapsed Members.

The following have lapsed for non-payment of 1918 dues:

Adams, E. L.,	Boardman, W. C.,	Booth, V. J.,
Barker, Joseph F.,	Bolland, J.,	Bouyoucos, S. J.,
Bergh, Otto L.,	Bonazzi, A.,	Carroll, J. S.,
[illegible]ford, E. E.,	Bonnett, R. R.,	Carter, L. M.,

Collins, M. W. H.,
Cook, I. S., Jr.,
Cox, Jos. F.,
Crabb, Geo. A.,
Cramer, W. F.,
Criswell, Judson,
Crosby, M. A.,
Davison, W.,
Derr, H. B.,
Dickson, R. E.,
Doryland, C. J. T.,
Dougall, Robert,
du Buisson, J. P.,
Duggar, J. F.,
Ellis, Orland I.,
Ewan, A. E.,
Finnell, H. H.,
Fleming, Frank L.,
Fletcher, O. S.,
Foreman, L. W.,
Frank, W. L.,
Gilkerson, H. C.,
Gish, N. A.,
Guell, Aurelio R.,
Hanger, W. E.,
Hanson, H. P.,
Harrington, O. E.,
Haskell, E. S.,
Hill, P. R.,
Hodson, Edgar A.,
Hoke, Roy,
Holbert, J. R.,
Hopkins, Cyril G.,
Hurst, J. B.,
Hutchinson, W. L.,
Hyslop, Geo. R.,
Jackson, J. W.,
Jarvis, Orin W.,
Kemp, Arnold R.,
Kenney, Ralph,
Knutson, George,
Lechner, H. J.,
Letteer, C. R.,
Livingston, Geo.,
Long, David D.,
Longman, O. S.,
Luckett, J. D.,
McClymonds, A. E.,
McIntire, W. H.,
Marbut, C. F.,
Martin, Thos. L.,
Mathews, Oscar R.,
Maughan, Howard J.,
Miller, Frank R.,
Milner, F. W.,
Morison, A. T.,
Moynan, J. C.,
Mundell, J. E..
Murphy, Henry,
Nevin, L. B.,
Newman, C. L.,
Noyes, H. A.,
Olson, M. E.,
Osenbrug, Albert,
Prince, Ford S.,
Pritchard, F. J.,
Richey, F. D.,
Robertson, R. B.,
Rose, C. N.,
Schultz, H. H.,
Severance, George,
Shinn, E. H.,
Shoesmith, V. M.,
Sink, Stanley B.,
Smith, Howard C.,
Snyder, Robert M.,
Stewart, Robert,
Torgerson, E. F.,
Townsend, C. O.,
Van Evera, R.,
Wallace, R. C. E.,
Ward, Wylie,
Wascher, F. M. W.,
Winsor, L. M.,
Winwright, George,
Woo, Moi Lee.

MINUTES OF THE ELEVENTH ANNUAL MEETING.

BALTIMORE, MD., JANUARY 6–7, 1919.

First Session, Monday Afternoon, January 6.

The meeting was called to order by the Secretary-Treasurer in the absence of President Lyon and Prof. J. H. Shepperd was appointed Chairman. The following papers were presented:

1. Effect of Varying Degrees of Heat on the Viability of Seeds, by James L. Burgess (followed by a discussion).

2. Field Crop Inspection, a Necessity to Standardization and Crop Improvement in Cereals, by H. L. Bolley (read by J. H. Shepperd).

Second Session, Monday Evening, January 6.

Dr. Herbert Osborn, presiding.

Some Observations on Agricultural Conditions in England and France, by Dr. W. O. Thompson.

Influence of Higher Plants on Bacterial Activities in Soils, by Dr. T. L. Lyon, President of the American Society of Agronomy (read by Dr. C. E. Leighty).

The Problems of Permanent Pasture with Special Reference to its Biological Factors, by Dr. Herbert Osborn, President of the Society for the Promotion of Agricultural Science.

Third Session, Tuesday Morning, January 7.

3. The Small Grain Varieties of Utah, by George Stewart (read by F. S. Harris).

4. Fertilizer Experiments on DeKalb Soils, by Frank D. Gardner.

5. Green Sand Deposits as a Source of Potassium for Crops, by R. H. True.

6. Carrying Capacity of Native Range Grasses, by J. H. Shepperd.

Fourth Session, Tuesday Afternoon, January 7.

7. A Method for Determining the Proper Stand of Corn under Southern Conditions, by C. A. Mooers.

8. The Work of the Committee on Seed Stocks, by R. A. Oakley.

9. A Reason for the Contradictory Results in Corn Experiments, by Lyman Carrier.

Business Meeting.

The report of the Secretary-Treasurer, as presented elsewhere in this issue, was read.

The report of the Auditing Committee was then read by the Chairman, Frank D. Gardner, as follows:

REPORT OF AUDITING COMMITTEE.

Your committee has audited the accounts of the Society by the Secretary-Treasurer, Lyman Carrier, and find them to be correct.

(*Signed*) FRANK D. GARDNER,
C. F. MARBUT,
Committee.

REPORT OF THE COMMITTEE ON STANDARDIZATION OF FIELD EXPERIMENTS.

In the work of the Committee on the Standardization of Field Experiments, it was thought advisable this year to make a survey of the methods actually followed by investigators employing field plot experiments. The task of collecting this information was divided among the members of the committee, one taking the questions relating to size, shape, and arrangement of plots employed in soil-fertility investigations; another taking similar questions relating to field experiments with crops, and the third taking the questions regarding the use and management of check plots. In each case questionnaires were prepared and sent to the workers along these lines in the experiment stations thruout the United States. It was felt that the information thus gathered would be of value to the members of the Society and would be helpful later on in formulating some general rules for the guidance of experimenters planning new work along these lines.

FIELD-PLOT METHODS IN SOIL-FERTILITY INVESTIGATIONS.

Size of Plot.—The answers to the question regarding the size of plots employed in soil-fertility experiments showed that nearly all of the experiment stations are using several different sizes of plots. There are various reasons for this. In many cases the area of land available has been the determining factor. Sometimes the nature and extent of the particular experiment has influenced the size of plot employed. More often the ideas of the experimenter as regards the most suitable and convenient size of plot have been the determining factor and so successive workers making additions to field-plot experiments have laid out plots of different sizes. Even tho the work is quite similar in nature, we thus have sometimes as many as a half dozen different sized plots in the same experiment field.

Among the 29 stations answering the question, the sizes of plots employed vary from 1 acre down to 1/200 of an acre. It was not possible to tell from the answers just how many different sizes of plots are employed, because in many cases the question was answered by merely naming the extremes of variation in size. Neither was it possible to get an accurate idea of the average size of plots used, but it is probably somewhere between one-tenth and one-twentieth acre. Only one of the 29 stations is using plots as large as 1 acre or as small as 1/200 acre. Tenth-acre and twentieth-acres plots largely predominate, and fortieth-acre plots appear to stand next in numbers. Only a few stations are using plots larger than tenth-acre or smaller than fortieth acre. A few of the stations are using quarter-acre, fifth-acre, eightieth-acre, or hundredth-acre plots. In answer to the question, "What do you consider the ideal size of plot?", the great majority suggested the twentieth-acre and tenth-acre sizes. Only a few favored either larger or smaller plots for ordinary purposes.

Shape of Plot.—Twenty-two of the twenty-nine stations more or less definitely answered this question and it appears that the variations in shape are even greater than the variations in size. Nearly every experimenter has a different idea as to the best or most convenient shape of plot. In 20 of the 22 cases where shape of plot is specified, more or less rectangular plots are used, and in the majority of cases they are decidedly long and narrow. Variations run from twice to ten times as long as wide. In two cases square plots are used.

It was brought out in many of the replies that both size and shape of plot must necessarily vary according to the acreage and character of the land available and that no fixed system can be followed in all cases.

Arrangement of Plots to Overcome Variations in Soil Fertility.—The importance of arranging series of plots so as to equalize soil differences as much as possible is generally recognized by experienced investigators. A common practice is to lay off long, narrow plots at right angles to the main soil variations and to provide for making corrections for the variations in the other direction by the use of frequent uniformly treated check plots. The repetition of series of plots so as to have a similarly treated series for each crop in the rotation helps to equalize variations. Such repetition of series provides for overcoming the effects of seasonal variations upon different crops by making it possible to grow the several crops employed in the rotation every year. This, together with frequent checks and averaging the similarly treated plots in the several series over a period of years, is generally considered sufficient to overcome ordinary variations.

Replication of Trials.—On this point, it was not possible from the answers to tell to what extent replication is practiced. The question was evidently interpreted in two different ways, some taking it to mean the number of similarly treated sets of plots and others the number of times the whole experiment is repeated. In most cases, however, each series of plots is repeated as many times as there are crops in the rotation followed, as for example, a 4-year rotation of corn, oats, wheat, and hay would have four sets of similarly treated plots, one set for each crop and all crops grown every year. Actual replication of whole series of experiments is practiced by only a few of the stations, tho several expressed themselves in favor of it wherever practicable. However, the large amount of land and labor required is a practical difficulty involved in the frequent replication of field-plot experiments, which usually include a considerable number of plots.

Spaces and Borders.—As regards spaces between plots and borders around series, the practice is to have narrow untreated strips between plots and untreated borders around series, planted to the same crop and cut out or trimmed off at harvest time. Only a few considered spaces and borders unnecessary.

Frequency of Check Plots.—In answer to the question, "What is your practice as regards the frequency of check plots?", 33 answers were received. It was found that many of the stations did not follow any one standard system of arranging check plots and that in many cases the practice varies according to the particular experiment. At the same station, series of plots laid out at different times may have checks located at different intervals. Thirteen of the stations answering the question thus have more than one system in operation. It was not always possible from the answer to tell how many different systems

are in use. In the following classification of the number of stations using different frequencies of checks, some overlapping occurs, as some are using more than one system. At 4 of the stations, systems of plotting are used in which every other plot is a check. The system of having every third plot a check is used at 21 of the stations. Six of the stations reporting are using every fourth plot as a check; 10, every fifth; 3, every sixth, and 4, every tenth. One of the stations is using a check near the beginning and near the end of each series of plots. In one case only one check is used, located at the beginning of each series, and at two of the stations the checks are located at irregular intervals according to convenience or soil variation. In many cases, perhaps the majority, the field-plot experiments reported were laid out years ago and a considerable number of them were laid out shortly after the establishment of experiment stations in this country, when the men in charge had little experience back of them. In making suggestions for laying out new series of permanent plots for soil-fertility investigations, the great majority of those replying favored the use of frequent and regularly distributed checks. In most cases it is considered desirable to have a check plot on one side or the other of each specially treated plot.

Treatment of Check Plots.—To the question, "How should check plots be treated?", 32 replies were received. Here again the practice varies, some giving the check plots a standard maintenance treatment, but in the majority of cases the check plots receive no treatment in the way of additions to the soil other than the crop rotation. A few of the stations are using treated check plots in some experiments and untreated check plots in others. In classifying the replies to this question, it was found that the answers were not always definite. At least 7 of the stations are giving the check plots some definite and regular treatment, while 18 are using totally untreated check plots only, altho 9 of them think it might be advisable to give the checks some regular treatment calculated to keep them in a normal state of productiveness. In discussing the question from the standpoint of future work, 24 stations out of 32 answering the questions favor giving the plots which are used merely for checking purposes a uniform standard manurial treatment calculated to keep them in a reasonably productive condition, provided that one or more untreated plots are included in each series to show what will happen to the land if crops are continually removed and nothing returned. The most commonly suggested treatment is a uniform dressing of manure. Some favor liming only, others a green manuring at certain regular intervals. Many of the workers along this line feel that the totally untreated plot becomes more and more unsatisfactory for checking purposes as the fertility runs lower and lower, and the results of the special treatments studied become unduly exaggerated. In a few cases, it is held that it is not possible to devise a system of treating check plots that will maintain uniformity, and it is believed that difficulties might arise which would be more serious than those connected with totally untreated checks.

Methods of Computing Results Through Check Plots.—To the question, "How should check plots be used in computing the results of field experiments?", 34 replies were received, but 6 of them were not definite enough to admit of classification. Twelve investigators of the twenty-eight definitely answering the question use the check plots by calculating the normal check yield

for each of the plots lying between the actual checks by assuming that the soil changes gradually from one check plot to the next. The difference between this calculated check yield and the actual yield is taken as the effect of the special treatment given to the plot. In 5 cases, the practice is to compare the specially treated plots with the average of the two nearest checks. In 3 cases, each specially treated plot is compared with the average of all the checks in the series. In 1 case where every third plot is a check, the treated plot is compared directly with its adjoining check. In 3 cases, sometimes the first system and sometimes the second system is used. In 1 case, sometimes the first system and sometimes the third is used, and in 2 cases, sometimes the second system is used and sometimes the third. In 1 case, either the third or fourth system is used and in another, any one of the four systems is used, according to conditions. In 1 case, the probable error is computed for each plot and stated after the actual yield for that plot. From the foregoing it is seen that here again there is no uniformity among the stations in the system employed, some using one and some another of four or five different systems. Check plots are used in one way or another by all of the stations answering the questions. However, it is doubtful if there is justification for so many different practices. Altho actual practices differ so widely, the preponderance of opinion is in favor of the use of frequent and regularly distributed checks, giving the check plot some regular soil treatment to keep it in a condition of reasonable productiveness and employing the check in making corrections by calculating the probable check yield for each plot according to the variation between the two nearest checks.

METHODS OF CONDUCTING EXPERIMENTS WITH CROPS.

A questionnaire relating to the methods used in conducting experiments with crops was sent to 76 agronomists. The principal questions related to the methods generally used in varietal, rate-of-seeding, date-of-seeding, method-of-seeding, and stage- or time-of-harvesting tests with small grain, cultivated crops, and hay and pasture crops in both field and nursery. Thirty-six replies to a part or all of the questions were received. These replies are summarized for each of the larger groups of crops as follows:

Size and Dimensions of Plots Used for Varietal, Rate-of-Seeding, and Date-of-Seeding Tests with Small Grain.—Thirty investigators reported the size of plots used for varietal, rate-of-seeding, and date-of-seeding tests with small grains. Of these, 2 use (not exclusively) plots larger than one-tenth acre in size. Twenty use plots varying in size from one-twentieth to one-tenth acre, 12 use plots less than one-twentieth but larger than one-eightieth acre, and 2 use plots one-eightieth acre in size or smaller. One investigator who uses fortieth-acre plots states that unpublished work indicates that one-eightieth acre is a good size.

Twenty-seven reports relating to varietal, rate-of-seeding, and date-of-seeding tests with rowed crops (corn, sorghum, cotton, cowpeas, soybeans, and potatoes) were received. Of these, 3 use plots larger than one-tenth acre, 18 use plots from one-tenth to one-twentieth acre, 16 use plots less than one-twentieth but larger than one-eightieth acre, and 5 use plots less than one-eightieth acre in size.

Twenty-nine investigators reported on varietal and rate- and date-of-seeding

tests with hay and pasture crops (alfalfa, clover, and grasses). Of these, 7 use plots larger than one-tenth acre, 21 use plots from one-twentieth to one-tenth acre, 8 use plots less than one-twentieth and more than one-eightieth acre, and 4 use plots one-eightieth acre in size or smaller. Most of those who use plots larger than one-tenth acre do so for pasture experiments.

Twelve reported miscellaneous tests such as stage of cutting and time of harvesting in which different sizes than those reported for other tests were used. Of these, 3 use plots larger than one-tenth acre, 8 use plots one-twentieth to one-tenth acre, 3 use plots less than one-twentieth acre but larger than one-eightieth acre, and 2 use plots one eightieth acre in size or smaller.

Summarizing all crops and kinds of experimental tests, it appears that slightly more than half of the agronomists use plots varying in size from one-twentieth to one-tenth acre. Very few use plots larger than one-tenth or as small as one-eightieth acre. For small grains and rowed crops, plots less than one-twentieth but larger than one-eightieth acre are used almost as much as the one-twentieth to one-tenth acre sizes. Plots larger than one-tenth acre are used more extensively for hay and pasture crops than for small grains or rowed crops.

Thirty-one reported the number of rows per plot for tests with rowed crops. Of these 8 use plots consisting of one row, 12 use plots consisting of two or three rows, and 27 use plots consisting of four or more rows per plot.

All experimenters who gave dimensions reported the use of long, narrow plots, the ratio of width to length varying from about 1 to 4 to about 1 to 200. The average ratio for all reporting is about 1 to 28 for small grains, 1 to 15 for rowed crops, and about 1 to 10 for hay and pasture crops.

Number of Times Plots are Replicated.—Thirty-three replies relating to varietal tests with small grains were received. Six of these report the use of single plots. Twenty-one duplicate some or all of their tests, 17 replicate from two[1] to four times, and 5 replicate their tests more than four times in all cases or when time and ground permit. For rate- and date-of-seeding tests, 3 experimenters use single plots, 17 duplicate their tests, 14 replicate two to four times, and 3 replicate more than four times.

For varietal tests with rowed crops, 7 investigators report the use of single plots, 20 duplicate their tests, 16 replicate two to four times, and 2 more than four times. For rate- and date-of-seeding tests with rowed crops, 5 use single plots, 13 duplicate, 9 replicate two to four times, and 1 more than four times.

Of those reporting tests with pasture and hay crops, 8 use single plots, 15 duplicate their tests, 9 replicate from two to four times, and 1 replicates more than four times. A number who used single plots indicated that they did so only when land and facilities for handling the work made it impractical to do otherwise. In fact, only one investigator reported the use of single plots exclusively. In this case and in most of the others reporting the use of single plots, check plots were used.

In interpreting results of experiments in which replicate plantings are made, 16 compute the "probable error" and 13 do not.

Margins of Plots.—An inquiry was made as to whether the margins were harvested with the plots, removed before harvest, or whether the alleys and roadways were seeded solid to prevent the crop receiving water and plant food

[1] That is, three plots of each variety.

from the adjoining areas. Thirty-four replies were received. Thirteen reported that the outside rows or margins were harvested and included with the plots. Fifteen do not include the outside rows or margins with the plot; i.e., the outer edges are removed before harvest. Six follow the practice of seeding the entire alleys and removing the crop before harvesting the plots.

Some or all of those who make no provision for eliminating the marginal effect use very narrow alleys and one includes a part of the alley with the plots in computing yields in order to compensate for the food and water secured from beyond the edges of the plots. One investigator in tests with small grains seeds winter wheat in the alleys in the spring.

The Colorado station has determined for irrigated plots the lateral movement of water and surrounds the plots with borders which extend beyond the limit of safety.

Twenty-five replied as to provisions being made to prevent insect or fungus damage to adjoining plots because of the proximity of especially susceptible varieties, dates of cutting (as, for example, leaf spot on alfalfa, which may spread from a plot which is not cut to the new succulent growth of an adjoining plot and do more damage than if the entire field was cut at the same time) or special methods of seeding or cultivation. Fifteen reported that no such precautions were taken. The remainder endeavored to prevent such damage by grouping susceptible varieties, by eliminating susceptible varieties as soon as discovered, by early harvest of severely damaged plots, and by control measures.

Thirty-two agronomists reported regarding provisions made to prevent errors in experimental tests with rowed crops due to the competitive effect of adjoining plots, as, for example, shading by unusually tall varieties of corn, or early planted lots in time-of-seeding tests. Fifteen reported that no provisions of this kind are made. Five of the remainder group the varieties, and ten eliminate or reduce errors of this kind by planting extra or guard rows.

Variation in Size of Kernels in Varietal Tests.—The question was asked whether any provision is made to insure a uniform number of kernels per acre in varietal tests in which varieties with different sized grains are included. Twenty-three replies were received. Eleven increase the rate of seeding for large-kerneled varieties. Of the remainder, 10 reported that they do not consider the variation in size important or else they consider it impractical to eliminate this source of error for small grains.

Size and Dimensions of Nursery Plots.—Of 17 experimenters who reported on the size and dimensions of nursery plots for small grain, 13 use rows approximately 1 rod in length. Four reported the use of rows greater in length than 50 feet and one uses rows 100 feet in length or longer. One reports that blocks 16 feet long by 50 inches wide are used and another reports the use of plots 1 feet square. Those who use rows usually space them 1 foot apart, but this distance varies from 8 inches to as much as 18 inches.

As to the number of rows per plot, 9 reported that single rows were used, 8 used plots consisting of from two to four rows, and 3 used plots consisting of five rows for some or all tests.

For pasture and hay crops, 4 reported the use of single row plots, 6 the use of drow in 4 row plots, and 1 the use of 10-row plots. One uses small blocks as nursery

Replication of Nursery Plantings.—For small grains, 4 indicated that they do not replicate their plantings, 5 duplicate their tests, 10 replicate from two to four times, and 6 replicate five times or more. For rowed crops, 5 do not replicate, 6 duplicate their tests, an equal number replicate from two to four times, and 2 replicate five times or more.

Four use single plantings for hay and pasture crops, 5 duplicate, 4 use from three to five plantings, and 1 replicates five times or more.

Of 23 who use or have used single rows for nursery plots only 7 make provision for eliminating error due to the competition of adjoining rows. The impracticability of entirely eliminating such errors appears to have been one of the chief reasons for using plots consisting of more than single rows. Practically all who use single rows attempt to prevent erroneous conclusions by recording any unusual sources of error, as when some rows fail to germinate or are killed by cold or other causes.

Cooperative Experiments with Farmers.—Of 30 who sent reports relating to cooperation with farmers all but 6 indicated that cooperative experiments of some kind were conducted. All but 1 investigator consider them necessary. A few experimenters were emphatic in their expression of the necessity of such tests, while others appeared to consider them of little value from an experimental viewpoint.

Experiments in Technic.—Seven agronomists reported experiments now under way relating to the technic of conducting field experiments with crops, and others have work planned for prosecution after the war.

GENERAL DISCUSSION.

It is fair to say that the results of this questionnaire show a very lively realization of the importance of accurate field tests and an earnest endeavor to reduce such errors as far as possible with the money, time, and land available for experimental work. Many state that tests would be replicated a greater number of times and greater accuracy would be secured if it were possible to do so. It is especially encouraging to note that less than 20 percent of those who sent in reports depend on single plots, but replicate their tests from one to several times.

One need only compare the methods in general use by agronomists ten years ago with those used at the present time to appreciate the great improvement in technic that has taken place. That there is an appreciable variation in the soil from plot to plot was just beginning to be realized at that time. The use of check plots was by no means common and replication of plots was scarcely thought of. Variation of the soil is now one of the accepted tenets of agronomic science, and agronomists now replicate their tests almost as frequently as they formerly depended on single plots.

No doubt much or all of this improvement in methods is due to the agitation which resulted in the appointment by the American Society of Agronomy of the first committee on the Standardization of Field Crop Experiments and to the excellent experiments relating to the technic of field experiments conducted by members of the Society.

It would be surprising if the questionnaire had failed to show that there is need of more information of several kinds. There is much uncertainty as to the necessity of removing the border rows of field plots before harvest. There

are those who contend that, as all plots are affected alike, the increase in yield due to the marginal effect is comparative and may be ignored, especially if the alleys are narrow. On the other hand, the fact that nearly half of those sending in reports remove the grain from the alleys at considerable expense and inconvenience at a very busy time of the year shows there are some who do not share this view.

Much remains to be done before it can be safely asserted that any given size of plot is best for a given purpose, and experimenters are perhaps even more in the dark as to the number of replications necessary or desirable for each set of conditions. In nursery tests it is apparent that not all are convinced of the necessity of avoiding all chances of error due to the competition of adjoining rows.

Conclusion.

The committee regrets that the survey could not be made more complete. Questionnaires were directed to interested investigators at all of the State experiment stations, but only about 70 percent replied. The replies, however, include reports from all of the stations carrying on any considerable amount of field-plot experimental work and are sufficiently representative to give a fair idea of the various methods in operation. It will be seen from the foregoing summaries that there are great variations in the practices followed and many differences of opinion among the investigators concerned as regards the most desirable methods to follow. Circumstances, no doubt, alter cases and probably it would not be wise to lay down any hard and fast rules from our present knowledge of the factors involved. The relative merits of different systems must receive further study and the committee strongly recommends that more of the members in position to do so undertake experimental studies with a view to determining the best and most practicable methods for the different lines of investigation requiring field-plot experiments. Doubtless a certain amount of standardization is possible and the members of this society should work together to that end.

Additions to Bibliography.

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Respectfully submitted,

A. T. WIANCKO,
F. S. HARRIS,
S. C. SALMON,
Committee.

REPORT OF THE COMMITTEE ON TERMINOLOGY.

Your Committee on Terminology begs to report that, owing to the conditions arising out of the war, the work of the Committee has been practically suspended during the past year, but it is purposed now to continue it with vigor. Thus far four contributions to the subject have been published, and when the whole subject has been covered it is proposed that these be combined and published as an official glossary. Yours very truly,

C. V. Piper,
Chairman of the Committee.

REPORT OF THE EDITOR.

Because of the increased cost of publication and the reduced income of the Society due to loss of members to military service and for other reasons, it has been necessary to curtail the year's volume of the Journal of the American Society of Agronomy. Including the December number, the volume consists of 360 pages, as compared with 432 pages printed in 1917 and 400 pages printed in 1916. Not including the December number, the forms for which are not yet made up, the 1918 volume has included 41 papers by 55 authors, representing 19 States and the District of Columbia. This is one more paper than was included in the considerably larger volume of last year, showing a desirable tendency toward shorter papers. To illustrate these papers, 9 plates and 46 text figures have been used.

The editing of the Journal has been accomplished with considerable difficulty, as the editor has been either traveling or on emergency work outside Washington during all except two months during the year. It has often been difficult to reach him promptly with papers for publication or with proof, and consequently the promptness and regularity of issuance of the Journal has not been up to the desired standard. As a large agricultural library has not usually been at hand, it has been impossible to check many of the citations of literature, and therefore these have not always been as accurate or as uniform as could be wished. The editor has refrained from resigning only because he has felt that others who might do the work are as heavily loaded with emergency duties and perhaps as badly handicapped as he.

Necessarily, the size of the annual volume is dependent on the Society's income. It is hardly likely that printing costs will further increase, so that if the present membership can be maintained the 1919 volume should be at least as large as the one just published. With the favorable conclusion of the war, however, the Society's membership should be largely increased, and this increase will naturally bring prosperity to the Society's publication. The maintenance or the progress of the Journal of the American Society of Agronomy is dependent largely on the whole-hearted support of the Society's membership.

The editor regrets exceedingly that it is not possible for him to attend the eleventh annual meeting of the Society, the first that he has missed since his official connection with the organization. He trusts that it will be a very interesting and successful one, and that it will mark the beginning of a new era of progress for the American Society of Agronomy.

Respectfully submitted,

C. W. Warburton,
Editor.

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Vol. 2, cloth, 154 pp., 16 papers, 1910. Vol. 4, cloth, 160 pp., 20 papers, 1912.

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